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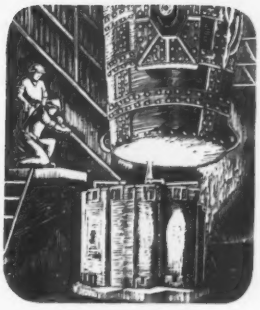

Studies on Ingot Feeder Heads

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SYNOPSIS

This paper describes the experimental work carried out in the Steelmaking Laboratories of the British Iron and Steel Research Association on methods of increasing the efficiency of feeder heads for killed steel ingots. Results of some works trials supplement the results of small-scale experiments.

The methods are based principally on the findings that the hot-top lining needs to have low heat capacity to give high efficiency. The most effective methods involve the use of exothermic material, and this is possible in a variety of ways.

The report gives recommendations for improving methods of hot-topping and the increase in yield which may be expected in each case. 1431

THE FEEDING of killed steel ingots, with particular reference to improving the efficiency and economy of the process, has been the subject of experiments in the B.I.S.R.A. Steelmaking Division Laboratories.

This work has proceeded on two lines: the study of heat flow in hot-tops* described by Fenton,† and the development of improved feeding methods based on the results of the heat-flow studies. This latter is the subject of the present paper, which describes experiments carried out both in the B.I.S.R.A. laboratories and in members' works.

The results of the work on heat flow in the 15% firebrick hot-top of a 5-cwt ingot are summarized in Table I; the top of the head was covered with vermiculite in this case.

Table I shows that the major part of the heat lost goes in heating the refractory of the hot-top. Reduction in this source of heat loss should result in a substantial saving in head size. The loss to the refractory depends principally on the heat capacity, and the use of materials of lower heat capacity than firebrick has therefore been investigated. Improved efficiency must also result if the hot-top generates heat under the conditions of use and hence the use of exothermic material has been investigated.

Fenton also found that with no top addition the heat loss from the top surface increases markedly and probably accounts for 25–30% of the increased total heat loss. Attention has also been paid, therefore, to this aspect of hot-topping practice.

EXPERIMENTAL PROCEDURE

Casting Technique

The experimental procedure for the trials in the laboratory was standardized as far as possible to limit the number of variables and so ensure reproducible results. It was briefly as follows. One grade of steel only was used, conforming to En 8 specification, the analysis being 0·35–0·45% C, 0·60–0·80% Mn, 0·15–0·35% Si, 0·02–0·03% S, 0·03% max. P. The steel was melted in an arc furnace of 10-cwt nominal capacity, using a standard tube scrap charge and a standard melting method; 11½ cwt were charged, giving sufficient steel for two ingots per cast. Tapping temperature was 1600° C, giving a casting temperature of 1520–1530° C. Teeming was through a 1-in. fireclay nozzle direct into the moulds, which were of conventional plug-bottom design, giving ingots 9 in. square at the top, 8¼ in. square at the bottom, and 27 in. long in the chill. The ingot weight was about 520 lb, exclusive of head. All hot-tops were superimposed, the bricks or tiles either being in a cast-iron

* There is often some confusion over the terms 'feeder head' and 'hot-top', as they are generally regarded as synonymous. In this paper they are used to describe respectively the top part of the ingot and the refractory box which contains it. *Feeder head*—The upper portion of the ingot, the solidification of which is retarded, so that it remains liquid and feeds the shrinkage cavity which occurs as the lower portion solidifies. It is subsequently removed as 'top discard'. *Hot-top*—The refractory container at the top of an ingot mould by means of which the solidification of the feeder head is delayed until the ingot body is solid.

Feeder head volumes are quoted as percentages of the total ingot volume, i.e. combined volume of ingot body and feeder head, and discards as percentages of the total weight of ingot body and feeder head.

† G. Fenton, *J. Iron Steel Inst.*, 1957, vol. 186, Aug., pp. 396–405.

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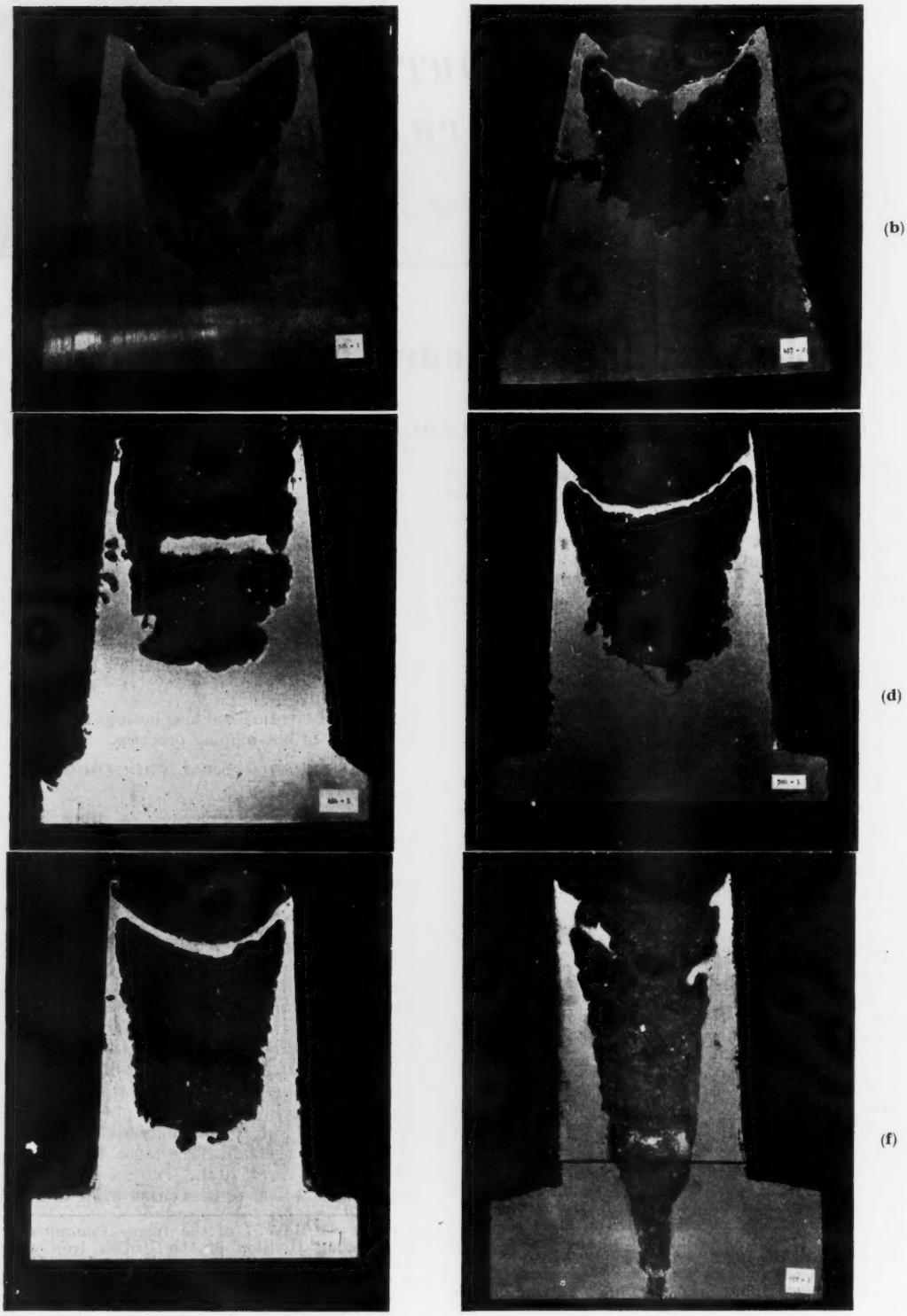
Mr. Marr and Mr. Fenton are with the Association's Steelmaking Division; Mr. Glaisher was also on the staff of the Division until earlier this year, when he joined the British Iron and Steel Federation.



(*a*) 14½% firebrick comparison (*b*) 14½% (*c*) 13% (*d*) 11½% (*e*) 10½% (*f*) 9½%

Fig. 1—Series of feeder heads cast in insulating brick

headbox or cemented together and to the mould top and suitably secured. Further details are given later.

Interpretation of Results

In practice, the assessment of feeding efficiency is the amount of top discard which must be taken after primary working to ensure a sound product. While this must be the main criterion of the effectiveness of a hot-top, it gives no direct evidence of the shape of the shrinkage cavity or the distribution of segregation. In the works trials described, feeding efficiency had to be assessed by this method, but in the laboratory experiments it was assessed by sectioning the ingot. The head was sawn off below the shoulder and sectioned longitudinally slightly off centre to allow for subsequent machining to the centre plane. The head section was then photographed, sulphur-printed, and where necessary drilled or sliced for chemical or spectrographic analysis. From the sulphur prints the top discard necessary to clear the pipe cavity and major segregation was then calculated.

In these experiments it was not usually possible to forecast beforehand exactly the size of head required, and heads were therefore often made larger than was necessary. Consequently, the unsound-metal figures quoted do not always include the whole head, as would be the case in works practice where the crop has to be taken at or below the shoulder. However, a reasonably accurate estimate of the optimum head size, where the limit of unsound metal coincides with the shoulder, can be obtained from these figures.

The standard against which the results obtained with modified heads have been compared was that of a normal firebrick hot-top, having a head volume of 14½% and covered with vermiculite grains after teeming. Previous experience had shown that this was the minimum size for a sound ingot with a hot-top of this type.

EXPERIMENTAL RESULTS

The results are considered under two headings:

(i) The use of alternative hot-top materials
(ii) The use of top additions.

Use of Alternative Hot-top Materials

Insulating Brick

As mentioned earlier, for high feeder head efficiency it is desirable that the hot-top refractory should have a low heat capacity. Because heat capacity is the product of specific heat and density, and the specific heats of practicable conventional refractories are all of the same order, a desirable feature of refractories for hot-tops is low density. Low-density refractories are also good insulators, and so high-temperature insulating bricks should be a good alternative to firebrick.

Table I

APPROXIMATE DISTRIBUTION OF HEAT LOSSES IN A FIREBRICK HOT-TOP

Source of Heat Loss	Total Losses throughout Solidification, %
From top	5
To heating firebrick	75
Through firebrick	12
To ingot body	8

Table II

RESULTS FROM INSULATING BRICK HOT-TOPS ON 5-cwt INGOTS

	Insulating Brick Tops					Standard Firebrick Tops
Base dimensions, in.	7½	6¾	6	5½	5	7½
Head volume, %	14½	13	11½	10½	9¼	14½
Unsound metal, %	6½	6	6	6	15	11

Preliminary tests of a series of high-temperature insulating bricks showed that certain makes were able to withstand attack by the molten steel better than others, and that heat losses to the different bricks varied somewhat. Two makes giving the best combination of these properties were selected for further trials. The bricks had densities of about 50 lb/ft³ and porosities of over 65%, compared with 120 lb/ft³ and 25–30% for firebrick.

A series of headboxes was made up of 1½-in. thick insulating brick in the usual form of a truncated pyramid, each having a 5-in. square top dimension and a slant height of 9 in. The base dimensions were varied from 7½ in. to 5 in. to give different head volumes when filled to a standard height of 8 in. The smallest of these gave a head without taper. All ingots had a top addition of vermiculite grains approximately 1 in. thick. The ingots were cast in pairs, the series including two standard firebrick hot-tops (head volume 14½%), and two ingots of each size of head were made in different casts. Table II gives the results obtained.

The heads made in insulating brick were more than adequate except for those of 9¼% volume; in these primary pipe extended well below the shoulder, and a discard of over 15% would have been needed to clear this. By using insulating-brick lining a decrease in head volume of 4–5% was made possible. The unsound-metal figures obtained from heads of various sizes were very similar, provided that the head sizes were adequate, and indicate that the use of the discard figure obtained on an oversize head should not lead to a large error.

Figure 1 illustrates this series of feeder heads and Fig. 2 shows three sulphur prints—one of the standard firebrick hot-topped head, one of an identical head made in insulating brick, and one of the optimum head of 10½%.

The results of three works trials using insulating brick tops are given in Table III. It will be seen that the improvement obtained with the insulating brick in the works was not as great as that in the laboratory experiments, although it is still appreciable on the 14- and 25-cwt ingots. This difference is probably due to the works trial hot-tops being reduced only in height, whereas the 10½% laboratory hot-top was

Table III

WORKS TRIALS WITH INSULATING BRICK HOT-TOPS

Trial	Ingot Size, cwt	Discard on Normal Ingot, %	Discard on Trial Ingots, %	Decrease in Discard, %	Av. Life of Tiles, casts
1(*a*)*	14	8·9	6·3	2·6	7+
1(*b*)*	14	7·7	5·8	1·9	7+
2	25	11·2	7·7	3·5	17
3	70	12·0	11·8	0·2	6

* In (*a*) no top addition was used, and in (*b*) vermiculite was used on both normal and trial ingots.

(*a*) 14½% firebrick comparison (*b*) 14½% insulating brick (*c*) 10½% insulating brick

Fig. 2—Sulphur prints of feeder heads cast in insulating brick

reduced only in cross-section at the base, compared with the standard firebrick hot-top. As shown by Fenton, the narrower head should be more efficient owing to lower heat losses to the ingot body.

Other works trials on 4-, 10-, and 15-ton ingots were carried out, but the hot-top bricks were so badly eroded in each case that they could not be re-used; also, no satisfactory ingot discard figures were obtained.

The life of the bricks used on the 14- and 25-cwt ingots may be regarded as satisfactory. In the former case, the bricks at first were supported in the headbox by a small ledge only, and this led to rapid wear at the base of the brick. A more substantial supporting ledge used in subsequent trials gave the longer lives shown in Table III.

The increased wear on the bricks with larger ingots is probably due to the longer solidification time. It is not recommended that they be used for ingots of over about 2 tons weight.

With careful bricking, there is no reason why a satisfactory life cannot be obtained with insulating-brick linings in most cases.

Recessed Tiles

The use of a type of firebrick tile with the back hollowed out is another method of reducing the heat capacity of a hot-top. Tiles of this type used at B.I.S.R.A. had an overall thickness of 1½ in., and were recessed to give a working face about ⅜ in. thick. The thin portion was strengthened by making the back in a honeycomb form. Size for size, this brick is lighter than a normal firebrick and therefore of lower heat capacity. Consideration of the results of the heat flow experiments given by Fenton, however, shows that the heat extracted from a feeder head by a ½-in. thickness of brick is only slightly less than that for a 1½-in. thick brick during the 20-min solidification period. This is because of increased radiation from the back of the ½-in. section. Consequently, there should be little difference between heads cast in the recessed tiles and heads made in firebrick hot-tops. However, one works reported that recessed tiles were giving lower discards and a laboratory investigation was therefore made with hot-tops of identical inside dimensions, one lined with a recessed firebrick tile of face thickness of about ⅜ in., and the other lined with 1½-in. firebrick of similar density. Vermiculite top additions were used in both cases. The head volumes were both large for the ingot size but, since they were the same, the feeding could be directly compared. The results are given in Table IV.

The practical trials agree with the theoretical consideration, showing that for these conditions the recessed tiles give no better result than do ordinary firebrick hot-tops. Figure 3 shows heads cast in recessed tile and in comparison firebrick hot-tops.

The recessed tiles stood up well in use, giving seven lives, with little patching needed. The seventh cast was short-weight and heavy slag eroded the tiles badly.

B.I.S.R.A. Double Headbox

In an attempt to make use of the low heat capacity and good insulating properties of vermiculite, a new design of headbox has been evolved in the B.I.S.R.A. Laboratories as described by Fenton. This consists of a thin sheet-steel liner, made in the usual shape of a truncated pyramid, which is studded or pierced to allow a thin facing of a refractory material, such as ganister or fireclay, to be applied and to adhere to the inside. This liner is enclosed in a larger, more robust outer container, and the intervening space filled with vermiculite granules or other highly insulating materials.

The prototype had inside dimensions corresponding to the 'standard' firebrick hot-top, namely 7½-in. square base, 5-in. square top, and 9-in. slant height. The inner steel liner was of ⅛-in. steel sheet and the lining of hot face material was ¼-in. thick.

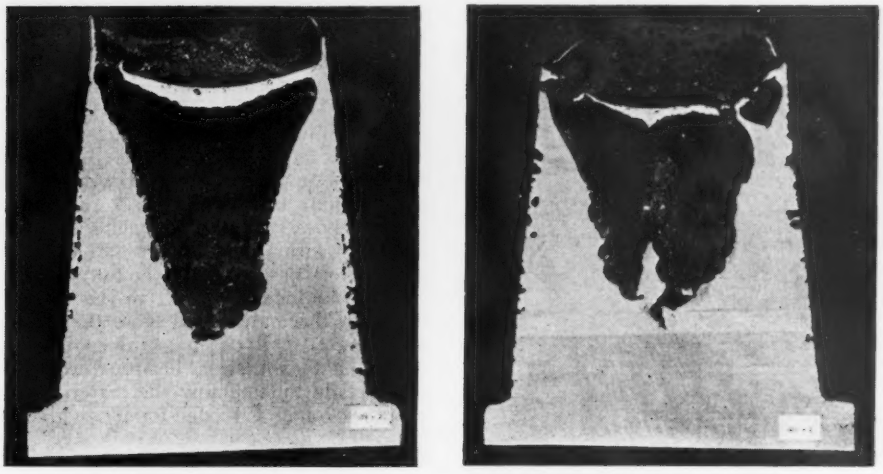
Six casts have been made in B.I.S.R.A. laboratories with this headbox; four had linings of ladle ganister, one had a ganister–vermiculite mixture, and the sixth an insulating concrete lining. The results are given in Table V. Heads 2 and 6 are shown in Fig. 4.

The mean of the first two trials shows a discard of the order of 8½% when a 14% head is used, which compared with a 11% discard from a 14½% firebrick hot-top is an improvement of about 2½%.

Table IV

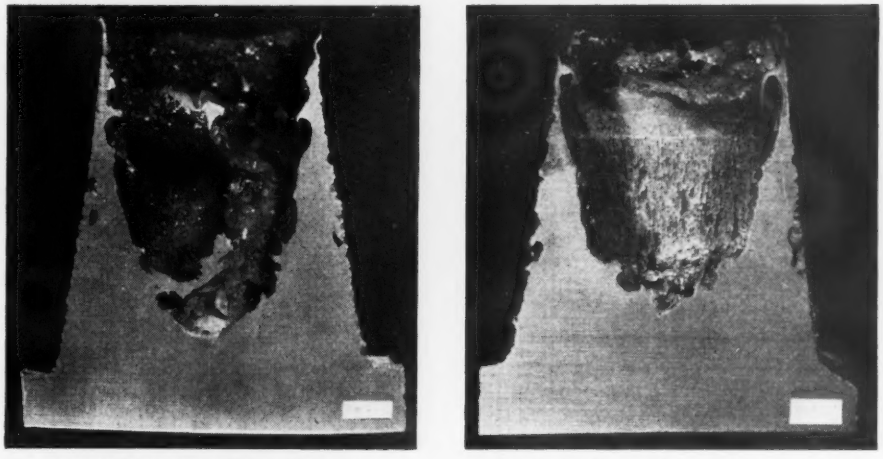
COMPARISON OF RECESSED TILE AND FIREBRICK HOT-TOPS (figures in %)

Recessed Tile		Comparison Firebrick	
Head Volume	Unsound Metal	Head Volume	Unsound Metal
17·8	9·4		
17·8	10·7	17·7	8·9
16·5	9·9	16·3	9·7
18·6	9·8		
Av: 17·7	10·0	17·0	9·3



(*a*) 16½% recessed tile (*b*) 16½% firebrick comparison

Fig. 3—Comparison of feeder heads cast in recessed tile and firebrick hot-tops



(*a*) 14½% as cast, discard 9%; ganister lining (*b*) 14% as cast, discard 6%; insulating concrete lining

Fig. 4—Heads cast in B.I.S.R.A. double headbox

The use of the insulating-concrete lining gave an improved result but there was considerable action in the head on casting, probably due to the combined water in the concrete.

The effective heat capacity of this headbox was calculated to be about two-thirds that of a firebrick hot-top of equal size. It is interesting to note that the heat capacity of an insulating-brick hot-top is two-fifths that of firebrick. The increase in yield of the double headbox would therefore be expected to be less than that for insulating-brick hot-tops, and this is borne out by the results quoted above.

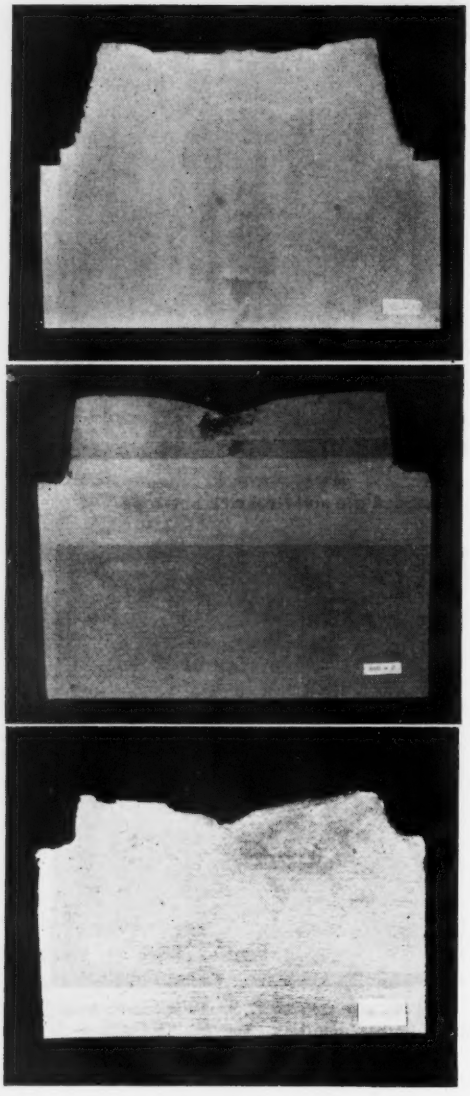
The full life of the headbox and lining has not been determined. On the prototype at B.I.S.R.A. the same refractory linings were used three times without much apparent wear or damage and the headbox itself was as good as new after six casts.

One works trial on 21-cwt ingots has been carried out, but the thicknesses of steel plate and refractory lining used were too great and the results were no better than those with comparable firebrick hot-tops. It is hoped that further trials with thinner steel plate and hot-face lining will give good results on larger ingots.

Table V

FEEDER HEADS CAST IN THE B.I.S.R.A. DOUBLE HEADBOX

Lining	Top Addition	Head, %	Unsound Metal, %
1. Ganister	Vermiculite	13·9	7·6
2. Ganister	Vermiculite	14·4	8·9
3. Ganister	Exothermic powder	13·6	9·6
4. Ganister	Exothermic + vermiculite	13·1	7·3
5. Ganister and vermiculite	Vermiculite	13·4	9·2
6. Insulating concrete	Vermiculite	13·8	5·6



(*a*) 10% (*b*) 7% (*c*) 5%

Fig. 5—Feeder heads cast in exothermic hot-tops

Exothermic Tiles

Exothermic sleeves have been used on the risers of both ferrous and non-ferrous castings for a long time, but the adaption of exothermic materials to steel ingot tops is comparatively recent. With exothermic material used as a headbox lining the effective heat capacity of the lining is reduced by the heat evolved by the exothermic reaction which occurs. With powerful exothermic materials the lining may even reach a higher temperature than the feeder head and will then give up heat to the head.

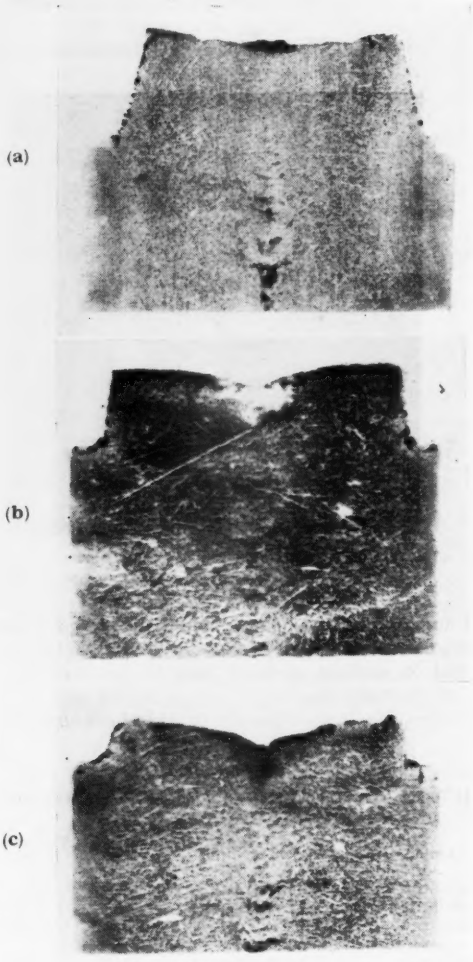
The exothermic materials used in the laboratory tests were supplied in the form of slabs, or as a powder for ramming round a former. They consist of aluminium powder, oxidizing agents, additions for controlling ignition temperature and burning rate, and a refractory base. Part of the oxygen for combustion of the aluminium comes from the air. The calorific value of the materials is more than double that of aluminium–iron-oxide mixtures.

The first exothermic hot-tops used at B.I.S.R.A. were made by ramming the material in a cast-iron headbox round a wooden former to give a 1-in. thick

Table VI

TYPICAL FEEDER HEADS CAST IN EXOTHERMIC HOT-TOPS

Head Volume, %	Unsound Metal, %
10·0	0·9
7·3 (tall narrow)	4·0
7·1 (squat)	2·1
5·1	3·4
5·0	3·8



(*a*) 10% (*b*) 7% (*c*) 5%

Fig. 6—Sulphur prints of feeder heads illustrated in Fig. 5

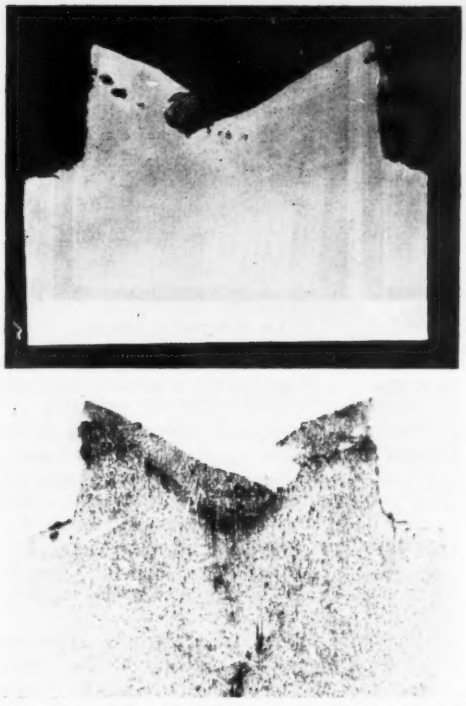


Fig. 7—Photograph and sulphur print of 8½% head cast in exothermic-lined firebrick hot-top

lining. A pad of the same material was made for the top of the feeder head. The initial feeder head was cast to 10% and produced excellent feeding. The size of the head was reduced in subsequent trials until a 5% head was cast successfully. The results for a series of heads are given in Table VI; Figs. 5 and 6 show respectively the sections and sulphur prints of typical heads from this series. The heavy **V**-segregation and porosity visible in these and other sulphur prints is associated with mould taper and occurred in all ingots, irrespective of the type of hot-top employed.

Table VII

HEADS MADE IN EXOTHERMIC-FACED HOT-TOPS

Backing Material	Head Volume, %	Unsound Metal, %
Firebrick	14·0	7·6
Firebrick	8·5	7·1
Insulating brick	8·4	1·0
Insulating brick	7·4	1·1
Insulating brick	6·8	2·3

These results show that excellent feeding can be obtained on small ingots by the use of exothermic materials. Although the 7% and 10% heads show somewhat smaller theoretical discards than the 5% head, in practice their discards would be greater because the sound metal in the head would also be wasted when the crop was taken at or just below the shoulder. The 5% head shows segregation extending just below the shoulder (Fig. 6c); the optimum head volume would therefore be between 5% and 6%.

The application of this process of hot-topping is being actively pursued by the makers of the materials, and it is now being used on a full production scale in a number of works for ingots of up to about 10 cwt, but so far only on alloy steels. Works trials are in hand on a range of larger ingots, the biggest so far being of 20 tons, and present indications are that the method has wide applications.

Close liaison between B.I.S.R.A. and manufacturers of exothermic materials has been maintained and has led to certain improvements. The major advance has been the development of composite or duplex tiles.

Composite Tiles

The main objection to exothermic materials for hot-tops on ordinary-quality steels has been the cost. There are two ways of trying to surmount this problem; one is to use cheaper materials, and the other is to reduce the amount of material needed to give the desired result.

There are a number of grades of exothermic material available, and in general the quick-acting most closely controlled grades are the most expensive. Costs can be kept to a minimum by using the grade giving

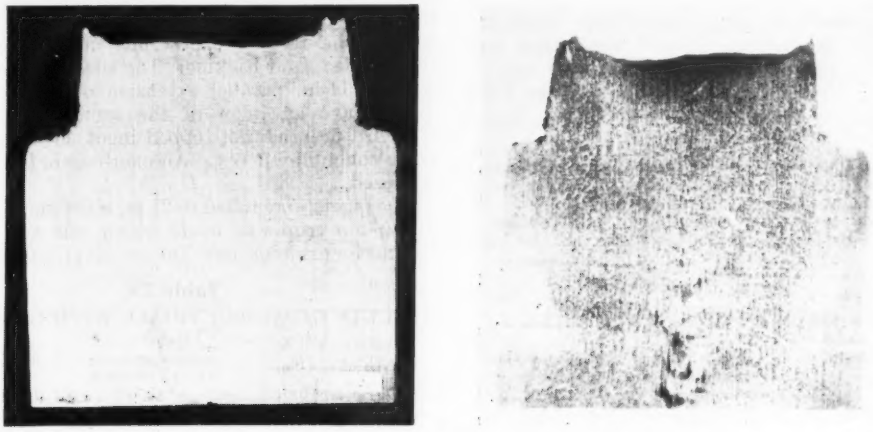
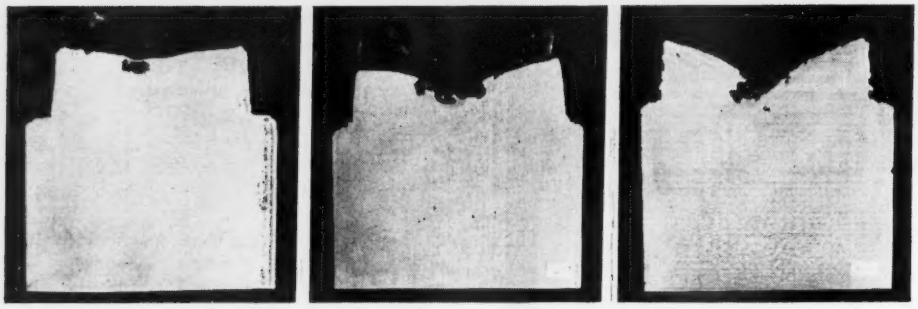


Fig. 8—Photograph and sulphur print of 7½% head cast in exothermic-lined insulating-brick hot-top



(*a*) 1 in. exothermic, ½ in. sand (*b*) ½ in. exothermic, 1 in. sand (*c*) ½ in. exothermic, 1½ in. sand

Fig. 9—Feeder heads cast in composite sand-backed exothermic tiles

greatest benefit at an economic cost, which would have to be ascertained by a trial in most cases. However, a larger saving would be made if the quantity of exothermic material could be reduced substantially. Experiments were therefore made in which exothermic facings were used on firebrick and insulating-brick backings. Layers ¼ in. thick were made by mixing the exothermic powder to a plaster-like consistency which was trowelled on to the brick and dried thoroughly.

The results of some of these experiments, all of which had exothermic top additions, are given in Table VII, and two of the sectioned heads are illustrated in Figs. 7 and 8.

These experiments show that the use of a thin layer of exothermic facing on a firebrick backing under these conditions results in a reduction in unsound metal of 3%, which is about equal to that obtained by substituting insulating brick for firebrick. The use of the ¼-in. layer of exothermic on an insulating brick backing gave excellent results, comparable with those obtained with 1-in. of exothermic tile.

Further experiments showed that the burnt-out exothermic layer remaining after casting an ingot could only be removed without damaging the brick backing if a wash of parting medium was put on the brick before coating it with exothermic facing. The most suitable material was found to be starch paste.

A works trial of 10 hot-tops for 14-in. ingots was carried out to assess the practicability on a production basis. The headbox linings were 1½-in. insulating brick and the exothermic material was mixed with water to give a trowelable consistency and applied ⅜ in. thick. After being used five times, the brick linings were still in satisfactory condition, but a number of difficulties were apparent:

(i) The number of operations entailed was excessive—stripping the old lining; applying parting wash; applying exothermic lining; drying

(ii) Drying the hot-top was difficult and tedious as temperatures above 250° C could not be used because of the inflammability of the lining

(iii) It was not easy to apply a uniform layer of the correct thickness of exothermic material.

A further trial was made using a ½-in. layer of exothermic material on a firebrick-lined hot-top of a 3½-ton 21-in. square ingot. Drying and venting of the material proved impracticable and it is thought that this method of using exothermic material will only prove favourable if it can be applied mechanically and in a dry state. The possibility of using CO_2–sodium-silicate bonding with this aim in view is being investigated by the manufacturers.

An alternative approach is to use integral composite tiles or sleeves, where the lining and backing are made in one pressing, for use once only. Trial batches with a backing of CO_2-bonded sand were manufactured for B.I.S.R.A. The slabs were 1½ in. thick overall and had facings of ¼ in., ½ in., and 1 in. of exothermic material. These slabs were made into hot-tops 7½ in. square by 4½ in. high. The average results obtained are given in Table VIII.

Photographs of typical sectioned feeder heads and their sulphur prints are shown in Figs. 9 and 10. From these results it is clear that, when using a bonded-sand backing, over ½ in. exothermic facing is necessary to give a result comparable with a full exothermic tile; the actual limit is probably nearly 1 in.

A series of works trials to assess the practical aspects of the use of these tiles was made on 11-in. square 14-cwt ingots, with medium-alloy steels. The hot-tops consisted of four tiles, 7 in. high, which had a ½-in. face of exothermic material and ½-in. CO_2-bonded sand backing. The tiles were hung 6 in. into an 11-in. parallel extension of the mould top which gave an ingot of the same weight as the standard firebrick hot-topped ingot, but reduced the head volume by 5–6%. An exothermic top addition was used.

The ingots were rolled to 2½-in. billet and a standard 12½% top crop was made which was cut into 1-ft lengths for examination. The results given in Table IX

Table VIII

HEADS MADE IN COMPOSITE TILES

Thickness, in.		Head Volume, %	Unsound Metal, %
Exothermic	Sand		
1	½	9·5	1·8
½	1	9·3	3·3
¼	1¼	8·7	8·3

Table IX

RESULTS OF WORKS TRIALS WITH COMPOSITE TILES

Type of Hot-top	Number of Trial Ingots Examined	Sound Billet* Yield, %
Normal firebrick	19	83·5
Composite tile	26	88·6

* Prime product after bottom crop, dressing, etc., in addition to top discard.

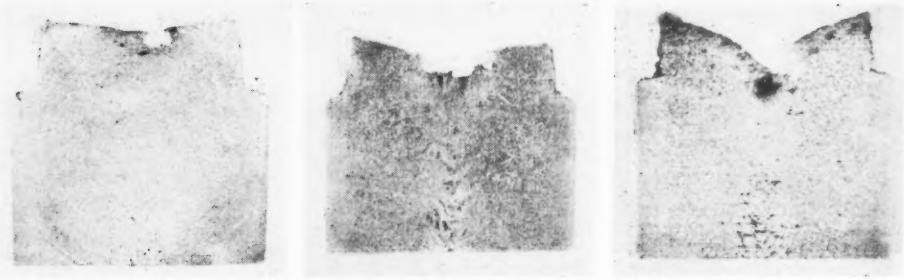


Fig. 10—Sulphur prints of heads shown in Fig. 9

show that an increased billet yield of over 5% could be obtained for the same cast weight.

The results of trials with composite linings of all types show that, to be as efficient as a full exothermic tile, the heat capacity of the backing material and the thickness of exothermic material must be related. Since, for the refractories under discussion, porosity and heat capacity are directly related, graphs can be drawn which determine the thickness of exothermic required with a given size of head and porosity of backing material. Figure 11 shows such a graph for a 9-in. ingot.

Trials are now being made by refractory manufacturers and the manufacturers of exothermic materials in conjunction with B.I.S.R.A. to produce a cheap expendable tile having an insulating refractory backing with an exothermic facing.

Combustible Tiles

This section includes all those forms of hot-top linings which ignite and burn on use, excluding aluminium-based exothermic mixtures. Generally the base is carbonaceous.

A laboratory investigation was made of hot-tops built from tiles of a type which is used in full production at several steelworks in Europe. The material used is mainly coke breeze and sawdust, bonded with sulphite lye, with the working face and lower edge covered by a thin refractory wash to minimize carbon pick-up.

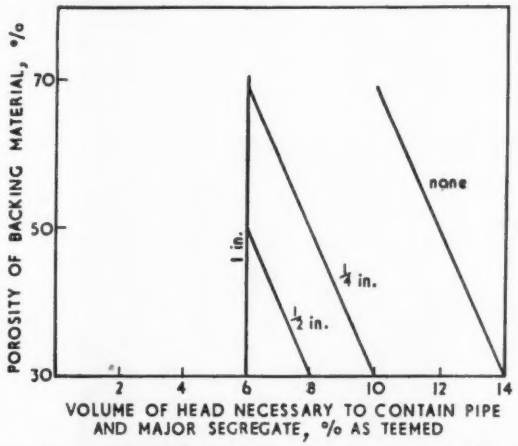


Fig. 11—Relationship between size of head required and porosity of backing material for composite tiles. The graph is for 1 in., ½ in., ¼ in., or no exothermic facing, and is for 9-in. ingots

The tiles were supplied 1 in. thick and were made into hot-tops 7½ in. square by 4½ in. high. By teeming to different heights, head volumes of 11% and 9½% were made. The top addition to the head in both cases was vermiculite. On the smaller head the segregation extended into the ingot body and a theoretical discard of 14·2% was needed. The larger head proved just sufficient to ensure that the major segregation was confined to the head. A theoretical discard of 6·7% was necessary to clear the pipe and segregation in this case.

The sectioned heads were sampled at selected spots near the surface and the ingot body and no appreciable pick-up of carbon was found. Figure 12 shows the results for the 11·0% head.

The tiles were rather friable but this may be because they were an experimental batch made for this investigation without proper equipment, whereas normal production sizes of tiles were said to be made under closer control and consequently to have better shape and strength.

Figures quoted by the makers show an increased yield of 5–8% obtained on the Continent, but only 3–3½% has been gained in the trials carried out at B.I.S.R.A. This may be attributed to the fact that the tiles manufactured in the U.K. are not yet up to the Continental specification.

A single trial of another type of carbonaceous refractory gave a result comparable to that on the 11% head above.

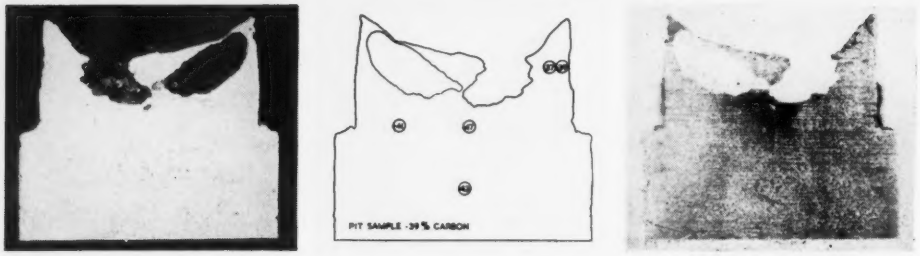
Use of Top Additions

As shown in the paper by Fenton, if the top surface of an ingot head is left unprotected after casting, large heat losses occur. In most practices, of course, some top addition is made. It was also shown that the

Table X

EFFECT OF VARIOUS TOP ADDITIONS

Top Addition	Head Volume, %	Unsound Metal, %
Nil	14·7	12·5
1 in. vermiculite	14·7	11·0
½ in. exothermic (loose powder)	14·3	9·7
½ in. exothermic (rammed pad)	14·6	8·8
1 in. exothermic (loose powder)	14·7	8·7
½ in. exothermic (loose powder) + 1 in. vermiculite	14·2	8·4



(*a*) Photograph (*b*) Analyses to investigate carbon pickup (*c*) Sulphur print

Fig. 12—11% feeder head cast in combustible tiles (carbonaceous type)

use of an inert insulating material such as vermiculite reduced these losses to a low level. Additional experiments have been carried out mainly to determine the effects of exothermic top additions.

A standard firebrick hot-top was used, with 7½-in. square base, 5-in. square top, and 9-in. slant height, filled to 8 in. high; this gave a head volume of 15%.

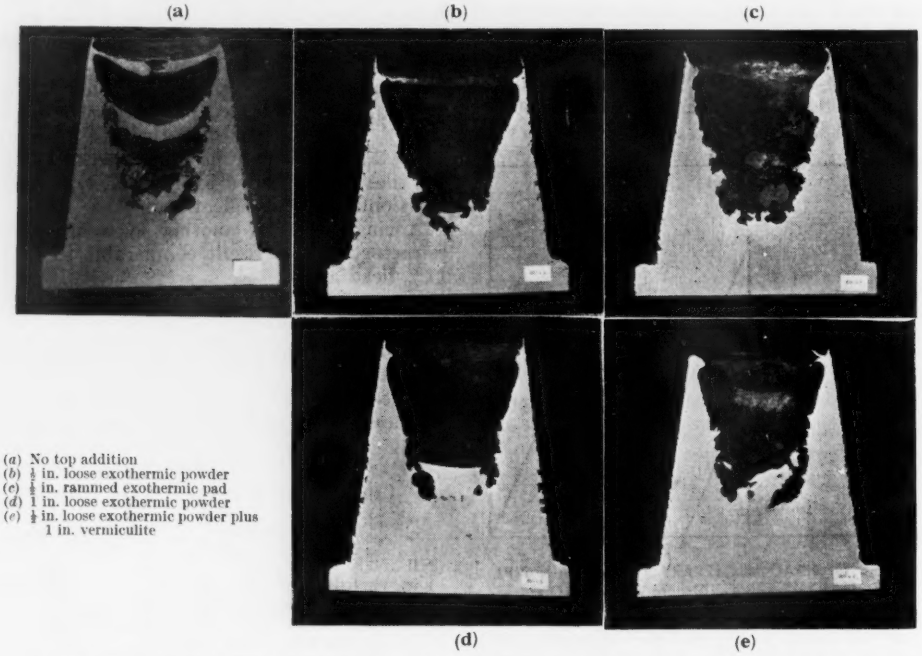
Ingots with no top additions were first cast to give the conditions used in some works practices, and these were followed by ingots on which top additions of vermiculite, exothermic material, and combinations of both were used. The results are given in Table X and the sectioned heads are shown in Fig. 13.

The vermiculite granules used in these laboratory tests and also in certain works trials generally gave a reduction of unsound metal of about 1½–2%. Where inert material is used the type is not thought to be critical, so long as it is refractory and insulating. It is reasonable to assume that the other insulating materials, such as kieselguhr, would give comparable results. The use of carbonaceous combustible mixtures in works trials has given results comparable with those obtained with vermiculite. Little more could be expected in the absence of a highly exothermic reaction since heat losses using vermiculite are very low.

The use of the aluminium-based highly exothermic materials gave a further 2% decrease in unsound metal when compared with the vermiculite alone, as shown in Table X.

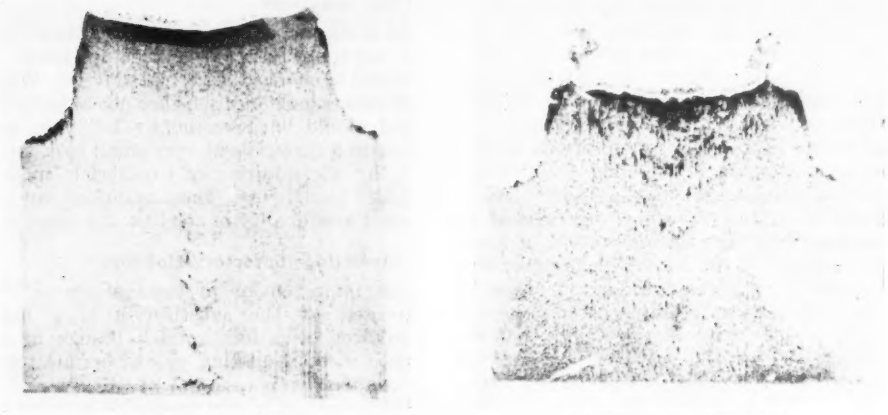
Table X shows that the exothermic materials in pad form have an advantage over those used loose, and that 1 in. of loose powder is better than ½ in. Vermiculite together with exothermic material allows a smaller amount of the latter to be used. The series of heads made at B.I.S.R.A. is illustrated in Fig. 13. The absence of bridging, with exothermic top additions, clearly shows the improved feeding.

The necessity for an exothermic top addition when using exothermic hot-top tiles is shown in Fig. 14. The first sulphur print is of a feeder head made in a



(*a*) No top addition
(*b*) ½ in. loose exothermic powder
(*c*) ½ in. rammed exothermic pad
(*d*) 1 in. loose exothermic powder
(*e*) ½ in. loose exothermic powder plus 1 in. vermiculite

Fig. 13—Series of heads cast in 14½% firebrick hot-tops with various top additions



(*a*) Exothermic top addition (*b*) Insulating top addition only

Fig. 14—Comparison of feeder heads cast in exothermic tiles

composite hot-top (insulating-brick backing, exothermic facing) with exothermic top addition and shows that the segregation is confined to a narrow band on top of the head. The second print illustrates a head cast in an identical hot-top but with vermiculite insulation only on the top. In this case the segregation is noticeably greater and is associated with a very porous cone extending below the shoulder This can be attributed to heat losses from the top surface.

DISCUSSION

The work described has shown that there are several ways of improving feeder-head efficiency, some giving large and some only small improvements.

Probably the easiest to apply to normal practice, when firebrick hot-tops are used, is the addition of materials to the top of the feeder head after casting. Top additions of anti-piping compounds are standard practice in many works, the benefit amounting to perhaps 2% increased yield, and this can be obtained with either inert insulating material or a combustible mixture of carbonaceous matter and refractory. Little difference should be expected between the two as the hot-top heat losses are in both cases reduced to a low level. If strongly exothermic mixtures are used, especially with an insulating cover, a further 1–2% increase in yield should be obtained.

The efficiency of an exothermic top addition is greater when it remains in place, rather than sinks with the head, when it may expose the surface of the head metal to the atmosphere; it is believed that a hard coking exothermic mixture will give best results. The use of a preformed slab would in theory be an ideal way of making the top addition, but difficulties in handling may arise.

Although top additions alone give small benefits compared with other methods, they are relatively cheap and easy to apply; they are especially useful on deep-piping qualities of steel.

From trials on a range of ingot sizes using headboxes lined with insulating bricks, it has become apparent that though this method is applicable to small ingots, the tiles are not sufficiently robust to withstand use on large sizes. The life of the brick was low in a first preliminary trial on 14-cwt ingots but, by strengthening of the bottom edge by a 1½-in. firebrick course, quite adequate lives were obtained. On much larger sizes the hot-tops failed mechanically on the first cast, probably because the longer solidification period of the ingot meant that the bricks remained at a high temperature for a long time and softened appreciably, leaving the brick susceptible to physical damage on stripping.

The use of insulating bricks is recommended, together with an insulating top addition, as a reasonably cheap way of obtaining an increased yield of approximately 3%, but only on ingots up to a maximum weight of 2 tons. The refractory costs when using these tiles will probably be about six times those when using normal firebrick hot-tops, as the tiles cost about three times as much and are expected to give only half the life. The cost for the top addition would be only of the order of a few pence per ton of steel treated. Additional labour costs for rebricking would have to be taken into account, but the resulting increased yield should offset the increased costs.

Suggestions have been made that a veneer of dense firebrick could be used as a hot-face lining in an insulating-brick hot-top to increase its life, but as this would have to be of the order of ½ in. thick or more for manufacturing purposes, an increase in yield would probably not be obtained on small ingots, since by far the largest portion of heat removed from the feeder head would be stored by this ½-in. layer. On larger ingots (e.g. over 5 tons) this arrangement may be practicable.

Although there have been no extensive trials with the B.I.S.R.A. double headbox on a production basis, it is possible that this design of hot-top will be applicable to the larger sizes of ingot. It is important that the interior steel lining and its protective facing of refractory should be as thin as possible, commensurate with the ability to withstand sustained temperature and ferrostatic pressure, so as to give the greatest efficiency.

The use of exothermic hot-tops can be regarded as a development of the hot dozzle, but the reduction in heat-absorbing capacity is taken to the point where no heat is extracted by the hot-top, which attains a temperature of 1500–2000° C. Reproducible results

can be obtained with this method since there are no variations in temperature, as there are with hot dozzles. Another advantage over the heated dozzle is that no pauses in teeming are needed to set the hot-top in place, especially beneficial when teeming titanium steels and others which easily 'crust'.

The need to use exothermic top additions in conjunction with exothermic hot-topping practice has been illustrated, and it must be remembered that, as the heat losses to the hot-top lining are reduced by lowering its heat capacity, the proportion of losses from the top surface of the head will increase; it is therefore necessary to prevent these top losses by using a highly efficient top addition. The process is metallurgically sound: some works report that the ingot bodies are sounder and that easier forging can result. The one adverse point that has arisen out of the trials at B.I.S.R.A. is that there can be some aluminium pickup by the feed metal from the hot-top. This is of such a level as to be insignificant in most cases though it would be advisable for any steelworks to check the pickup by its own method of analysis and standards.

Composite exothermic tiles are being vigorously developed and significant factors have emerged from various trials. As a result many production tiles are now made with a bonded silica sand backing. This has the advantage of decreasing the amount of exothermic material and producing a more robust assembly. An appreciable decrease in cost has therefore been possible in some cases where reductions of up to 50% of the weight of exothermic material have been made. Whether the use of more expensive backings of lower heat capacity would be economical remains to be judged from further trials.

The high cost of exothermic materials, together with the fact that the tiles are only used once, makes exothermic hot-topping a relatively expensive process compared with conventional methods, costing very approximately £1 per ton of steel treated. This should be balanced against the increased yield of about 7% which would in many cases make it well worthwhile, especially in highly alloyed steels, where it is in fact rapidly gaining popularity.

Combustible tiles, though used extensively on the Continent, where some of the raw materials are cheap and plentiful, have not proved very promising. Though cheaper than exothermic tiles, they give lower yields and on the results of the few trials at B.I.S.R.A. do not appear to be economical. The yields were very similar to those obtained when using insulating-brick hot-tops, but as the combustible tiles are only used once they are more expensive.

In the foregoing discussion it has not been possible to draw any firm conclusions on the economic aspects of the various methods of hot-topping. This is because conditions, existing techniques, and costing methods vary so much from one works to another. Both the economics of using new methods and the increase in yield to be obtained must be assessed for any set of circumstances by practical trials.

RECOMMENDATIONS

Several methods of improving yields from hot-topped ingots can be suggested.

1. Top Additions

It is recommended that top additions be made to all hot-topped ingots, especially where it is not possible to change the normal practice. With firebrick hot-tops, where additions are not already used, ingot yield should be increased by 1–2% by addition of insulating materials at very small cost, and by up to 3% by the addition of exothermic materials at a slightly higher cost. These additions can be made on almost any quality of steel on any ingot size.

2. Insulating Refractory Hot-tops

An improvement in yield of up to 3% can be expected by the substitution of a high-porosity insulating brick for firebrick linings in headboxes. The use of insulating or exothermic top additions in conjunction is essential.

This method is only applicable to ingot sizes below about 2 tons, because of the physical strength of the refractory, and care must be taken to provide adequate support by the hot-top casting. The method is suitable for all steel qualities.

3. Exothermic Hot-tops

The use of exothermic hot-tops is strongly recommended for alloy steels. For ingots of over about 9 in. square the exothermic material can most economically be used as the facing of composite tiles. In addition to the reduced amount of expensive material required, such tiles have greater strength for handling. For ingots of below about 9 in. square, tiles made of entirely exothermic materials may be more economical, since manufacture is simpler. Generally, a reduction of head volume of up to 7% will be possible with these hot-tops when used in conjunction with an exothermic top addition, but this may be higher.

For smaller ingots a quick-burning top addition is needed; for those of 9 in. or over a slower rate of reaction is desirable and an additional top cover of inert insulating material may well prove beneficial.

It is recommended that practical trials with exothermic hot-tops be made by low-alloy and carbon steel manufacturers in order that the economics of this process be assessed under their own conditions.

4. B.I.S.R.A. Double Headbox

This design cannot at present be recommended for general use as no trials have yet been made to determine the minimum thickness for large ingots. Tests are being made at B.I.S.R.A. on hot-tops for 4-ton ingots and it is hoped that production trials will be arranged as a result.

Acknowledgments

The authors are indebted to members of the Ingots Committee of B.I.S.R.A. for their guidance and to Mr. P. E. Hobson and members of the Electric Arc Furnace Section of the Steelmaking Division for assistance with the experimental work. Acknowledgment is also made to the management and staff of those steelworks where works trials were carried out, and to the manufacturers of refractory and exothermic materials: their assistance and interest have been extremely helpful.

Mechanism of Formation of Metal Particles in Scale on Nickel Steels

By K. Sachs, Ph.D., M.Sc., A.I.M.

SYNOPSIS

The metal particles entangled with the oxide in the inner layer of the scale on nickel steels form by the competitive operation of two mechanisms: the preferential oxidation of iron leading to the enrichment in nickel of metal entrapped in the advancing scale, and the transient solution of nickel in the wüstite followed by its precipitation on suitable nuclei. Metal particles interrupt the countercurrent diffusion of metal and oxygen ions through the oxide lattice, performing a function similar in principle to that of porosity. With the aid of these concepts it is possible to account for the effect of furnace atmosphere and nickel content on the structure of the inner scale layer and for the distribution of metal particles and of nickel through the thickness of the scale. 1367

THE INTERMINGLING of oxide and metal in the scale is a familiar feature of the oxidation of alloys. Subcutaneous oxide globules, intergranular oxidation, or the formation of a subscale layer are observed when relatively small amounts of readily oxidizable elements are alloyed with a metal having somewhat lower affinity for oxygen. If the more readily oxidized metal predominates, the other components tend to concentrate in the metal phase and metallic particles are often found embedded in the scale. In the scale formed by the oxidation of nickel steels, metal particles enriched in nickel are present.[1, 2] Depending on the nickel content of the steel and the partial pressure of oxygen, the metal may form a filigree pattern or a group of isolated particles.[3] The scale on steels can generally be divided into two or three layers and the nickel is concentrated in the innermost zone, corresponding to the dimensions of the original specimen[2]; within this zone there are systematic variations in nickel content with distance from the metal/oxide interface.[4]

The metal particles are formed because iron is oxidized more readily than nickel and because nickel oxide is unstable in the presence of iron oxides containing more than 72% iron.[2] The thermodynamic reason for the existence of the particles does not explain their form and distribution nor the mechanism of their formation. In principle, there is no reason why there should not be a sharp boundary between an iron oxide scale containing no nickel and a metallic core correspondingly enriched in nickel.

The concentration of nickel in small particles implies diffusion of nickel atoms towards selected areas, through either the metal or the oxide lattice. Both diffusion processes raise theoretical difficulties: movement through the metal lattice implies uphill diffusion, from areas of low nickel content, corresponding to the ' bulk composition ' of the steel, to areas of high nickel content in the particles; diffusion through the oxide lattice implies solution and subsequent precipitation of nickel via the oxide phase, although it is known that nickel oxide is unstable. These difficulties can be resolved by a consideration of the atomic events at the metal/scale interface. Here, an austenite lattice with a few nickel atoms in substitutional solid solution is in contact with a wüstite lattice. At equilibrium the wüstite is saturated with iron, but in a growing scale iron diffuses outward through the lattice and oxygen diffuses inward, so that there is a tendency for the oxide to dissolve iron, e.g. for iron atoms to join the wüstite lattice. As nickel atoms are left behind on the austenite lattice while iron atoms are dissolved, the concentration of nickel at the interface rises sharply and nickel tends to diffuse away from the surface to the interior. Any volume of metal surrounded by oxide would gradually shrink and all the nickel present in the original volume would concentrate in a metal particle entrapped in the scale. Although nickel oxide is not stable in the presence of wüstite, nickel atoms might be surrounded and entrapped by the advancing oxide. Such nickel atoms could be regarded as defects in the wüstite lattice; they would presumably diffuse through the oxide and precipitate on suitable metallic nuclei.

It appears, therefore, that diffusion of nickel is possible through both the metal and the oxide lattice, that the nickel-rich particles may form by entrapment in the advancing scale or by the precipitation of nickel taken into transient solution in the oxide. The probability of nickel atoms entering the wüstite lattice is greater the faster the rate of advance of the oxide relative to the rate of diffusion of nickel in austenite. To some extent, the advance of the oxide into the core is slowed down by the presence of nickel; diffusion of nickel is certainly not so fast that the advancing interface drives the nickel before it and concentrates it in the core. There appears to be a reasonable balance between the two rates, which suggests that both entrapment and precipitation mechanisms may operate in practice.

The experiments described in this paper demonstrate that both entrapment and precipitation occur, that entrapment is more important under conditions of slow oxidation, when the partial pressure of oxygen (or its equivalent, the dissociation pressure of the wüstite near the interface) is low, while precipitation is more noticeable in the early stages of oxidation, when the scale is still fairly thin. The interaction of the two mechanisms fully accounts for the complex distribution of nickel content and metal particles in the scale which has been described in some detail in an earlier paper.[4] The empirical relationship between the severity of the oxidizing conditions and the nickel content of the steel, which has been dealt with in another paper,[3] is tied up with the influence of nickel on the interdiffusion of iron and oxygen in the oxide lattice which also conditions the porosity in the scale. A study of the influence of nickel content and furnace atmosphere on porosity is described in the present paper, and it is shown that the part played by metal particles in the process of oxidation is rather similar to that of pores in the scale.

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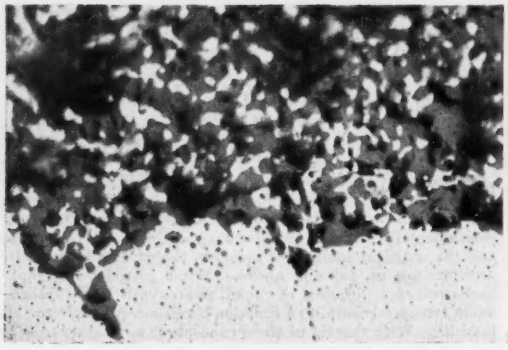


Fig. 1—Coarse-grained 1½% Ni steel after 16 h at 1050° C under a ' protecting box ' × 300

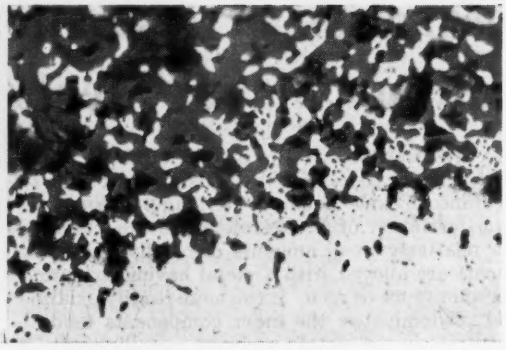


Fig. 2—Fine-grained 1½% Ni steel after 16 h at 1050° C under a ' protecting box ' × 300

ENTRAPMENT AND PRECIPITATION OF METAL PARTICLES

Influence of Austenitic Grain Structure

It is reasonable to suppose that the distribution of particles entrapped *in situ* would bear a recognizable relation to the structure of the original steel, while precipitation on accidental nuclei of material ' diffusing ' through the oxide lattice should result in a random distribution. The actual location of particles in a number of specimens was examined from this point of view. Specimens of 1½% Ni steels with and without small additions of aluminium were scaled in a gas furnace under a ' protecting box,' which reduces access of oxygen to the surface and thus lowers the effective partial pressure of oxygen in the atmosphere, for 16 h at 1050° C. The microstructures are shown in Figs. 1 and 2; the incipient intergranular oxidation of the core reveals the grain boundaries of the austenite at the interface and demonstrates that the steel without the aluminium addition (Fig. 1) had a much coarser grain size than the aluminium-killed steel (Fig. 2). The metal particles in the scale bear no relation to the grain structure of the austenite; the inference is that they were formed by precipitation.

In very thick scale deposits, on the other hand, it has been found that the metal filigree near the core displays some relation to the original grain structure. Figure 3 shows the structure near the interface in a selected field on a specimen of 1½% Ni steel scaled without a protecting box for 24 h at 1250° C in a gas furnace. It will be seen that thick intergranular oxide present in the core projects into the scale and is bounded by parallel films of metal, doubtless enriched in nickel due to removal of surrounding iron by the entrapment mechanism. Further out, however, these ' intergranular films ' have disappeared and merged with the rest of the oxide because the clearly defined metal films at their edges have been partially or completely dissolved. At the centre of a similar specimen scaled for a very long time (Fig. 4) the oxygen gradient was so shallow that oxidation progressed less by a systematic advance of the interface than by a slow growth of oxide globules nearest the scale. This growth of globules led to entrapment of nickel-rich films, forming a filigree within grains separated from the core by grain boundary oxide. Some of these isolated grains in Fig. 4 are only partially oxidized, half the grain being metallic while the other half consists of the metal filigree and oxide globules. Comparison of such grains with others which are completely occupied by the filigree structure shows that the proportion of metal to oxide is uniform in all parts of the filigree structure and therefore at all stages of its growth within a grain.

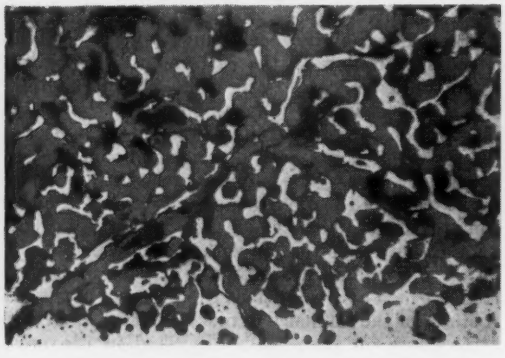


Fig. 3—Metal particles in thick scale near interface of 1½% Ni steel specimen freely exposed in gas furnace at 1250° C for 24 h × 150

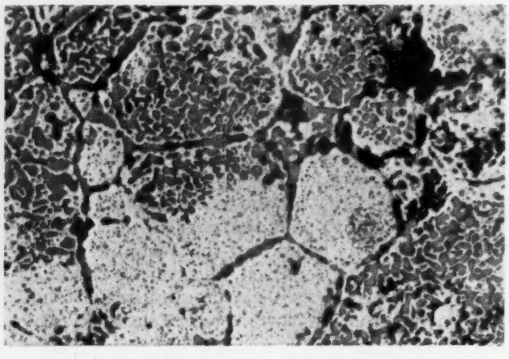


Fig. 4—Metal particles in thick scale formed on 1½% Ni steel specimen oxidized for 35 h at 1000° C and 7 h at 1220° C under a 'protecting box' × 100

There has been no directed segregation of nickel, no tendency for nickel to diffuse away from areas which are undergoing oxidation to others a little further from the metal/oxide interface. The whole appearance of the structure, the isolation of entire grains, and particularly the retention of metal filaments near the grain-boundary oxide, point to the operation of the entrapment mechanism. It is clear, however, that diffusion of nickel atoms away from the interface is so slow that nickel does not move even across a single coarse grain in the time it takes for the growth of oxide globules to extend over the grain.

These experiments show that thin coherent filaments near the core of heavily scaled specimens, where the partial pressure of oxygen is comparatively low and the rate of oxidation correspondingly slow, are formed by the entrapment mechanism. The discrete particles of metal further out in the thick scales (Fig. 3) are probably the remains of 'entrapped' filaments. In thinner scales, however, there are no filaments near the core (Figs. 1 and 2) so that it appears unlikely that filaments had been present at an earlier stage; the inference is that in these specimens the metal particles formed by precipitation.

Precipitation of Metallic Particles

Although the random distribution of metal particles in the thinner scales illustrated in Figs. 1 and 2 suggests that precipitation from the oxide lattice may play an important part in the origin of the metallic particles, direct evidence of the movement of nickel through oxide could only be supplied by specially designed experiments. The object of these experiments was to ascertain whether nickel particles could form in iron oxide at some distance from their source, i.e. outside the dimensions of the original nickel-containing specimens. Experiments on the movement through the scale of copper and nickel markers placed on the surface of mild-steel wires have been reported elsewhere.[5]

In this context, the effect on the scales formed on mild steel of the presence of large pieces of nickel was studied in an experiment using a mild-steel specimen with nickel wires inserted in two holes, so that one peg projected beyond the specimen on one face, while the other was left flush. The composite specimen after scaling for 36 h at 1250° C under a small protecting box in a gas furnace is shown in Fig. 5. Figure 6 shows metal in the scale on the

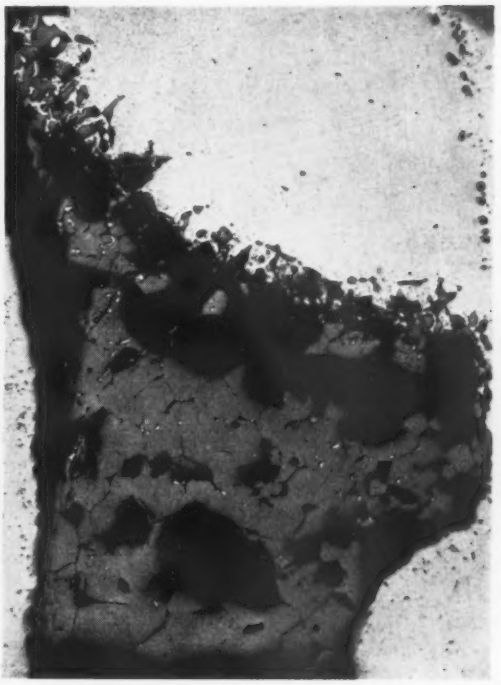


Fig. 6—Metal particles in scale between nickel inserts × 50

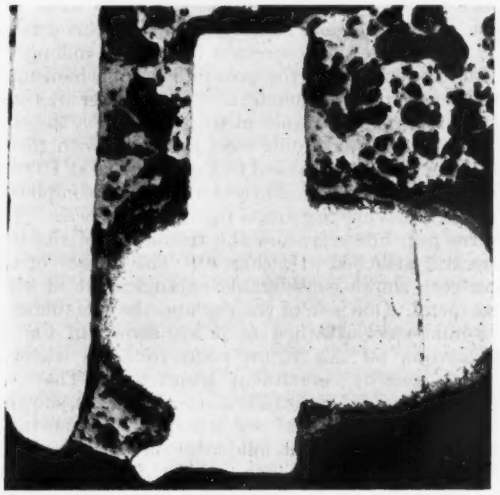


Fig. 5—Mild-steel specimen with nickel wire inserts oxidized for 36 h at 1250° C under a 'protecting box' × 10

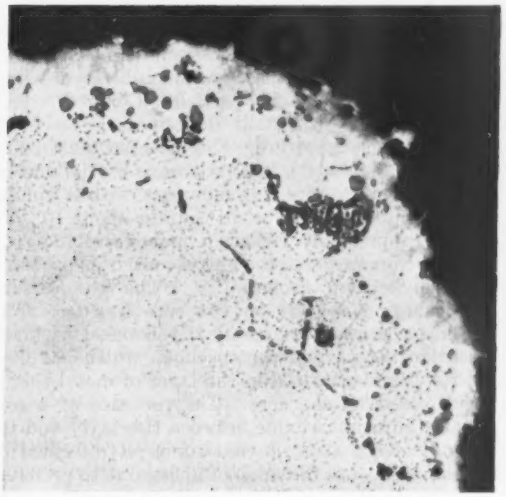


Fig. 7—Nickel-rich layer containing martensite on core of 1½% Ni steel oxidized for 120 h at 1150° C in electric furnace × 100

Fig. 8 × 20

Fig. 9 × 50

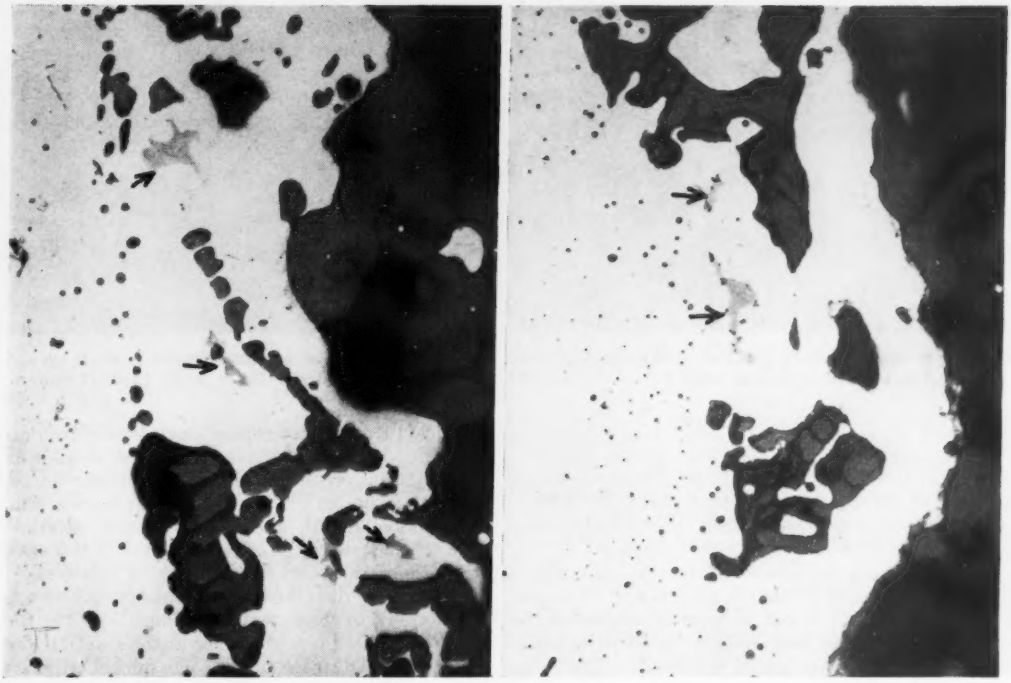
Figs. 8 and 9—Central nickel peg; arrows show second phase martensite

bottom face of the specimen where the partial pressure of oxygen is slightly lower than elsewhere. There can be little doubt that nickel-rich metal particles have appeared in the scale formed on the mild-steel block at a considerable distance from the nickel inserts.

Interesting evidence of the movement of nickel through the scale was found on a specimen of 1½% Ni steel oxidized in an electric furnace at 1150° C for about 120 h. The surface of the metal core is shown in Fig. 7. The fine globules and intergranular films of oxide normally present in the outer layer of the steel core extend only as far as a well-defined irregular line. Beyond this line there is a metallic layer which contains some coarse oxide particles. Closer examination reveals that this metallic deposit on the steel core has a two-phase structure. The material must be an iron–nickel alloy which has undergone partial decomposition to martensite. Comparison with a similar deposit[6] which was known to contain about 10% Ni and was appreciably richer in martensite indicates that in the present case the nickel content is probably a little higher, e.g. around 15%. The scale beyond the nickel-rich deposit on the core was free from metallic particles. Presumably all the nickel originally present in the part of the specimen which has been oxidized is concentrated in the layer of metal that is superimposed on the core. The presence of a considerable amount of oxide between this layer and the core indicates that the layer cannot have formed by the gradual inward diffusion of nickel due to preferential oxidation of iron, because the advancing oxide has clearly overtaken the inward movement of nickel.

This specimen was characterized by exceptionally prolonged oxidation in a strongly oxidizing atmosphere. It is suggested that under these conditions, where a large amount of nickel is available owing to the oxidation of a thick layer of nickel steel, and where the oxygen gradient is still so steep that it permits only a relatively narrow band of metal–wüstite equilibrium, metal has been precipitated in the filigree on the inner layer of the scale until it forms a continuous and fairly thick coating; some iron and all the available nickel were precipitated in this way, so that nickel was concentrated in this deposit and a two-phase structure was formed on cooling.

The importance of the precipitation mechanism in the formation of a coherent nickel-rich layer was confirmed by the appearance of such a layer on the core of a heavily scaled mild-steel specimen with nickel wire inserts, freely exposed in a gas furnace at 1200° C for about 36 h. The mild steel was almost completely oxidized, leaving the nickel inserts in the scale. The centre peg, however, had the remainder of the iron core still attached to it (Fig. 8). The surface of the iron core shows considerable entanglement of scale and metal. One side of the peg and the remainder of the mild steel attached to it are shown in Fig. 9; the arrows on this figure point to fields where a second metallic constituent is present. They are illustrated at higher magnifications in Fig. 10, showing a field near the central peg, and Fig. 11, showing a field at the point of the mild-steel core furthest away from the nickel peg. The amount of martensite in the metal deposit is relatively small, but its presence can be regarded as proof of local enrichment in nickel. Thus in a mild steel scaled together with a nickel peg



Figs. 10 and 11—Nickel-rich layer containing martensite on mild-steel core attached to nickel peg × 300

(Figs. 8–11—Mild-steel specimens with nickel wire inserts freely exposed in gas furnace for 36 h at 1200° C)

it is possible for nickel to be deposited on the surface of the unoxidized core, as in nickel steels. This can only have taken place by nickel being dissolved from the peg and diffusing through the scale to be precipitated on the surface of the iron.

Some evidence for the operation of the precipitation mechanism has been presented; it remains to be shown that the theoretical difficulties are not insuperable. From the theoretical point of view it appears improbable that nickel ions should diffuse through the wüstite lattice because the solubility of nickel in wüstite is immeasurably small and nickel oxide is reduced to metallic nickel in the presence of wüstite.[2] This does not exclude the possibility that nickel might diffuse through wüstite, just as carbon diffuses through saturated ferrite in the spheroidization of pearlite, but it makes it necessary to demonstrate that some reaction occurs at the interface between wüstite and metallic nickel in spite of the fact that the two phases are in equilibrium. Such a demonstration requires micro-examination of nickel heated in direct contact with wüstite.

Powdered wüstite had been prepared in connection with spectrographic work described elsewhere[4]; short lengths of nickel wire of two thicknesses were placed in a small cylindrical die, wüstite powder was packed round them and the whole pressed at about 40 tons/in^2. This compact was heated *in vacuo* for 64 h at 1000° C. In order to confirm that the vacuum was hard enough to prevent oxidation of the wüstite or even the nickel, a heavily oxidized nickel wire was also placed in the evacuated tube; after the experiment the surface of this wire was completely metallic. In fact it was found that the wüstite itself was partially reduced to iron, probably because the experiment was carried out in an Inconel tube and the dissociation pressure of wüstite is appreciably higher than that of chromium oxide which is an important constituent of the scale formed on Inconel. A cross-section through the compact is illustrated in Fig. 12. The presence of iron particles in the wüstite is clearly apparent. The originally smooth surfaces of the nickel wires have become very irregular and oxide has penetrated deeply into the metal. Thus although nickel has neither oxidized nor presumably entered into stable solution in wüstite, a reaction has taken place which, without altering the compositions of the phases or the quantities present, has altered the mutual positions of some of the constituents.

DISTRIBUTION OF NICKEL IN THE SCALE LAYER

It has been shown that both entrapment and precipitation can occur under favourable circumstances. The actual mechanism responsible for the formation of the mixed oxide–metal structure in prolonged scaling in a gas furnace is most conveniently considered in the light of surveys of the distribution of various constituents across the thickness of the scale.[4] After normal scaling treatments a curve of spectrographic nickel content against distance from the interface shows a peak some way out in the scale, usually fairly close to the original surface of the specimen prior to scaling. The peak nickel content is so high that its formation proves the movement of

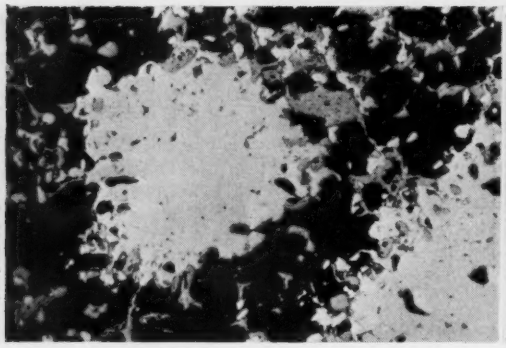


Fig. 12—Nickel wires pressed in wüstite powder, heated *in vacuo* for 64 h at 1000° C × 100

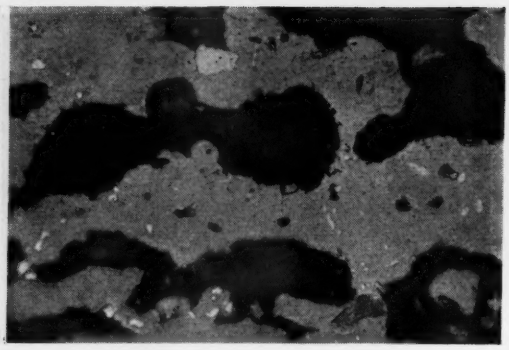


Fig. 13—Outermost metal particles in scale on 1½% Ni steel oxidized for ½ h at 1250° C under a 'protecting box' × 300

nickel over considerable distances. The location of the peak near the original surface, i.e. in the zone which was oxidized first of all, implies that the nickel cannot have diffused there through the metal lattice. This observation suggests that the precipitation mechanism plays a very important part.

At the scale/metal interface there is generally a rise in nickel content. The interface is not, of course, a single plane surface but a zone of mutual interpenetration of oxide and metal; the rise in nickel content is, therefore, quite gradual. The mere presence of oxide near the interface would itself be expected to lead to some increase in nickel content in that zone; the difference in spectrographic nickel determinations between nickel steel and oxide–nickel mixtures has already been dealt with in the earlier paper;[4] moreover, the actual nickel content should also increase because the appearance of oxide lowers the density of the material analysed. Assuming that the specific gravity of the steel is 7·8, that of wüstite 5·8, and that there is no porosity at the interface itself, the nickel content could increase by a factor of 7·8/5·8 at the most, giving a content of about 2% Ni near the interface of a 1½% Ni steel, and about 4% for a 3% Ni steel. Since some metal is left, particularly near the interface, the increase in nickel should be very much less. The observed spectrographic nickel contents close to the interface were of the correct order of magnitude. Some specimens of 3% Ni steels contained traces of austenite in filings taken near the interface, indicating localized increase in nickel content considerably above 4%, and this can only be accounted for by the movement of nickel over considerable distances.

Oxidation at the interface takes place by the dissolution of metallic iron in the wüstite lattice. The impoverishment of the interface in iron raises its relative nickel content. This mechanism does not lead to accumulation of nickel in the centre of the core by diffusion inward from the interface because the continuity of the outermost layers of metal with the main core is broken by the lateral spreading of oxide globules before any nickel has diffused away from the interface. However, the evidence of nickel enrichment at the surface of the core confirms that preferential oxidation of iron takes place at the interface.

Metal particles nearest the interface are enriched in nickel by the preferential oxidation of iron and are embedded in wüstite having the lowest possible oxygen dissociation pressure. Portions further out adjoin wüstite richer in oxygen which will have a tendency to dissolve metal, and metallographic studies have shown that the proportion of metal in the scale and the size of the particles diminish in this zone.[4] Iron will still be dissolved preferentially but the higher pressure of oxygen on the one hand, and the increase in the number of nickel atoms at the reaction interface on the other, may cause some nickel atoms to be entrapped in the wüstite lattice. They represent nickel particles too small to remain stable and will therefore travel through the wüstite lattice to precipitate at suitable nuclei. Nickel will be deposited further out in the scale, on particles already so impoverished in iron that the oxide no longer dissolves metal off them, and nearer the core where nickel-rich filaments are forming by the entrapment mechanism. This modifies the curve for the distribution of nickel in the scale, leading to relatively low values midway between the metal/scale interface and the nickel peak further out in the scale; either an actual decrease in nickel content may lead to a minimum between two peaks or there may be a flattening of the slope of the curve for the spectrographic nickel content.

Further out in the scale the curve for the apparent nickel content passes through a peak. This is associated with an increase in both the quantity and the particle size of the metal embedded in the scale. At constant nickel content one would expect a decrease in the amount of metal, and the fact that an increase is observed points to a local accumulation of nickel. This zone lies near the surface of the original specimen; Pfeil[2] has pointed out that at the beginning of oxidation of a nickel steel, both nickel and iron are oxidized together and the thin initial scale is so rich in oxygen that nickel oxide is stable. As the scale grows thicker its iron content increases and when it reaches a critical value (about 72%), the nickel oxide is reduced to metallic nickel. The presence of coarse nickel-rich particles and some local enrichment in nickel would therefore be expected in this zone. These nickel-rich particles are also very suitable sites for the precipitation of nickel atoms in transient solution in the oxide lattice and this leads to a gradual growth of the particles and further enrichment in nickel. Beyond

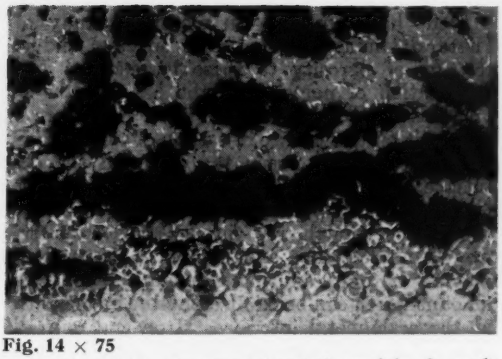


Fig. 14 × 75

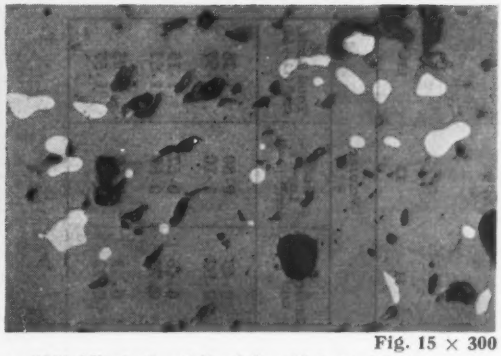


Fig. 15 × 300

Figs. 14 and 15—Outermost metal particles in scale on 1½% Ni steel oxidized for 6½ h at 1250° C under a 'protecting box'

the last peak there is a gradual fall in nickel content and in the amount of visible metal. Outside the boundary of the original specimen metal particles were found in only one instance and their presence was accounted for by the formation of magnetite at some stage in a very complex scaling treatment involving considerable temperature fluctuations.

The suggestion that nickel is precipitated on the outermost particles, near the original surface of the specimen, implies a growth of those particles which has to be proved by experiment. A specimen of 1½% Ni steel was scaled in a gas furnace at 1250° C for ½ h under a 'protecting box.' The portion of the scale containing the metal particles is illustrated at a magnification of 300 in Fig. 13. A similar specimen was oxidized for 6½ h under the same conditions and the metal particles in the zone where the nickel peak is usually found were so large that at a magnification of 75 (Fig. 14) they appear similar to those shown in Fig. 13; they are shown at the higher magnification in Fig. 15. These photographs demonstrate that in the course of oxidation, particles close to the surface of the original specimen grow in size, as they have previously been shown to be enriched in nickel, and this can only be explained by the precipitation of nickel which has migrated through the oxide lattice.

POROSITY OF THE SCALE

It is known that the amount of metal in the scale depends on the nickel content of the steel and on the severity of oxidation;[3] that there is a meta-stable relationship between metal particles and the oxide immediately surrounding them, so that the nickel content of the metal particles depends on the partial pressure of oxygen in the wüstite and the amount of metal present depends on the nickel content of the steel;[4] and it has just been shown that there are local variations in nickel content within the scale layer which point to the movement of nickel through the wüstite lattice. All this amounts to an empirical description of the origin and characteristics of the layer containing intermingled oxide metal, but does not explain why such a structure should form; the meta-stable relation between austenite of various nickel contents and wüstite with various oxygen dissociation pressures could in principle lead to a sharp interface as easily as to the intermingled structure that is actually found. The reason for the formation of metal particles in the inner layer of the scale is likely to be associated with the mechanism of oxidation by counter-current diffusion of iron and oxygen and the influence of oxygen partial pressure and of nickel content on this process. Some light is thrown on these processes by a study of the porosity of the scales formed.

There are two complementary reasons for the formation of holes in the oxide scale on steels. The density of iron oxide is lower than that of steel. When a given quantity of iron is oxidized, the oxide formed by it should occupy a larger volume than the iron it replaces. In the early stages of the formation of scale, oxide globules are entirely surrounded by metal and are presumably in a state of severe compression. In the thin continuous oxide layer at the interface these stresses are to some extent preserved and would be expected to lead to local fissures and holes. In thin films the compressive stress in the scale may lead to the formation of blisters supported inside by the pressure of non-oxidizing gases which have diffused into them.[7] However, such discontinuities in the scale might well be filled up later and in any case do not resemble the large spherical holes sometimes observed in really thick scales.

The second reason for the occurrence of porosity is the fact that iron tends to diffuse more rapidly than oxygen, presumably because it has a smaller ion. Differences in diffusion rates have served to explain the formation of voids in metallic phases[8, 9] and this effect, which might be expected to operate in scale layers, also accounts for the fact that discontinuities formed by other mechanisms are not repaired and explains how small defects grow into large holes. One account of the mechanism of formation of porosity at the metal/scale interface is given by Dravnieks and McDonald[10] who visualize such a profound difference between the diffusion of metal and oxygen ions through the oxide that continuity is lost at some points of the scale/metal interface. Holes are formed separated by columns of oxide which maintain contact with the main body of the scale layer. The holes are filled with oxygen at the dissociation pressure of the surrounding oxide which may oxidize the underlying metal, but the overall tendency will be to the formation of a porous layer close to the interface.

Table I

WEIGHT AND VOLUME OF SCALES

		1	2	3	4	5	6	7	8	9	10	11	12	13
Steel	Furnace	Scaled Specimen		Original Specimen		Core		Weight of Total Scale, g (1–5)	Weight of Core and Inner Layer, g	Weight of Inner Layer, g (8–5)	Weight of Outer Layers, g (1–8)	Volume		
		Weight, g	Displacement of Water, g or cm³	Weight, g	Volume, w/7·8 cm³	Weight, g	Volume, w/7·8 cm³					Inner Layer, cm³ (4–6)	Outer Layers, cm³ (2–4)	Total Scale, cm³ (11+12)
Mild steel	Electric	14·7180	2·53	13·4639	1·73	9·9337	1·27	4·7843	11·2450	1·3113	3·4730	0·46	0·80	1·26
	Gas	15·5637	2·83	13·4676	1·73	6·7380	0·86	8·8257	Layers could not be separated			0·87	1·10	1·97
1½% Ni	Electric	13·0554	2·19	11·8100	1·52	8·1223	1·04	4·9331	9·5506	1·4283	3·5048	0·48	0·67	1·15
	Gas	12·7367	2·31	11·0693	1·42	5·4381	0·69	7·2986	8·9480	3·5099	3·7887	0·73	0·89	1·62
3% Ni	Electric	13·1517	2·16	12·0040	1·54	8·6771	1·11	4·4746	9·8900	1·2129	3·2617	0·43	0·62	1·05
	Gas	13·6455	2·39	12·0006	1·54	6·3857	0·81	7·2598	8·8720	2·4863	4·7735	0·72	0·85	1·57

Pfeil[2] has combined an empirical study of the 'natural laminations' of scale on steel and of the relation of porosity to these laminations with an explanation of porosity on the basis of the higher 'natural' rate of diffusion of iron. Scale forming as a deposit on the surface of a piece of steel is compact, while the layer between the core and the original surface, i.e. the layer where oxide has replaced metal, is porous. The porosity of the inner layer reduces the cross-sectional area through which diffusion of iron can take place and thus cuts down the total amount of iron diffusing through the scale to the amount which can be oxidized by the oxygen arriving at the scale/metal interface. Iron can only diffuse outward through the oxide lattice; oxygen can travel inward by diffusion through the lattice and by the liberation of gas in the pores at the dissociation pressure of the surrounding oxide.

Since porosity is associated with diffusion through the oxide lattice, a study of porosity should throw some light on the diffusion process and an empirical examination of the effect of nickel on the porosity of the inner scale layer may help in understanding the influence of nickel on the scale formed on steels. In interpreting the results of porosity determinations it must be borne in mind that porosity of the scale involves the continuous growth and collapse of columns of oxide linking the metallic core and the bulk scale. The porosity must therefore be expected to show considerable random fluctuation both with time and at different points in the scale. For this reason the porosity of the entire scaled specimen or a substantial part of it must be considered rather than that in a particular field observed under the microscope, and chance variations between specimens must be regarded as unavoidable.

Two specimens of each of three steels, containing 0, 1½%, and 3% Ni, were scaled in an electric furnace at 1180° C for 8 h. One specimen of each steel was then oxidized for 5 h at 1180° C under a protective box in a gas furnace. The purpose of this second treatment in a less oxidizing atmosphere was to alter the structure of the inner scale layer with a view to increasing the proportion of metal particles.[3] In this way, two specimens of each steel were available with different structures, and the effect of severity of oxidation on the porosity could be assessed as well as the effect of nickel.

The scaled specimens were dipped in a solution of Perspex in benzene to seal discontinuities in the scale. The impregnated specimens were then weighed in air and water and the overall volume of the scaled specimen could be accurately calculated in terms of the displaced water. The weight and volume of the impregnation were neglected. Where possible, the outer scale layers were separated from the inner one and ground down for density determination; the inner scale layer was then removed from the core and similarly prepared. The densities of the oxide powders were determined in a 10-cm³ specific gravity bottle using toluene as the liquid. The volumes of the unoxidized specimens were calculated from their dimensions, those of the metallic core after removal of the scale were estimated by weighing in water. The difference in volume of the specimen before and

Table II
DENSITY OF SCALES

Steel	Furnace	Weight: Layer W, g	Weight: Sample w, g	Volume of Toluene displaced, v cm³	Density, $d = \frac{w}{v}$	Volume of Oxide in Layer, $V = \frac{W}{d}$ cm³
Inner Layer						
Mild steel	Electric	1·3113	1·0262	0·1946 0·1859 0·1950	5·35	0·245
	Gas	Layers could not be separated				
1½% Ni	Electric	1·4283	1·0605	0·1809 0·1855	5·79	0·246
	Gas	3·5099	1·9400	0·3442	5·64	0·623
3% Ni	Electric	1·2129	0·9796	0·1780	5·50	0·221
	Gas	2·4863	1·4020	0·2744	5·10	0·488
Outer Layers						
Mild steel	Electric	3·4730	3·2998	0·6294	5·24	0·664
	Gas	Layers could not be separated				
1½% Ni	Electric	3·5048	3·2023	0·6008	5·31	0·660
	Gas	3·7887	3·0276	0·5712	5·30	0·715
3% Ni	Electric	3·2617	3·2067	0·6254	5·13	0·637
	Gas	4·7735	4·1187	0·7662	5·37	0·889
Total Scale						
					$d = \frac{W}{V}$	
Mild steel	Electric	4·7843	...	...	5·27	0·909
	Gas	8·8257	7·7542	1·378	5·63	1·57
1½% Ni	Electric	4·9331	...	...	5·44	0·906
	Gas	7·2986	...	...	5·46	1·338
3% Ni	Electric	4·4746	...	...	5·21	0·858
	Gas	7·2598	...	...	5·27	1·377

after scaling corresponds to the volume of the outer scale layers and the difference between the original specimens and the metallic core represents the volume of the inner layer.

The experimental values and calculations are given in Tables I to III, and the results are summarized in Table IV.

The separation into layers was the least accurate feature of the experimental procedure and the values for the separate layers cannot be regarded as reliable. Nevertheless, it is clear that porosity is found mainly in the inner scale and that the outer scale is much more compact.

In general the density seems to increase with decrease in the severity of oxidation; the effect of nickel is not consistent, but it appears if anything to lower the density, which seems difficult to explain. The density of the inner scale layer of the 3% steel which underwent both oxidation treatments seems specially low, even lower than that of the outer layer, which undoubtedly has a higher oxygen content. In all other specimens the oxide near the core was denser than that further out. The results also indicate that the porosity of the entire scale tends to fall off with nickel content or with less severe oxidation. The volume occupied by scale is shown to decrease with nickel content in Table III (Table I indicates that this decrease in volume is not fully accounted for by the decrease in the weight of oxide formed). It follows that the observed decrease in porosity is not due exclusively to the lower figures for the density but represents a real effect.

Bearing in mind the random fluctuation of porosity, the weight of evidence is in favour of the conclusion that the presence of nickel lowers the porosity. Similarly, a more weakly oxidizing atmosphere leads to a lower porosity. According to Pfeil, the function of porosity is to cut down the area across which iron can diffuse and so reduce the amount of iron diffusing outward in any period to the amount entering the

Table III
POROSITY OF SCALES

Steel	Furnace	Inner Layers				Outer Layers				Total Scale			
		Volume		Difference, cm³	Porosity, %	Volume		Difference, cm³	Porosity, %	Volume		Difference, cm³	Porosity, %
		Bulk oxide, cm³	Scale layer, cm³			Bulk oxide, cm³	Scale layer, cm³			Bulk oxide, cm³	Scale layer, cm³		
Mild steel	Electric	0·24	0·46	0·22	47·8	0·66	0·80	0·14	17·5	0·91	1·26	0·35	27·8
	Gas	...	0·87	...	...	...	1·10	...	...	1·57	1·97	0·40	20·3
1½% Ni	Electric	0·25	0·48	0·23	47·9	0·66	0·67	0·01	1·5	0·91	1·15	0·24	20·9
	Gas	0·62	0·73	0·11	15·1	0·72	0·89	0·17	19·1	1·34	1·62	0·28	17·3
3% Ni	Electric	0·22	0·43	0·21	48·8	0·64	0·62	0·02	0	0·86	1·05	0·19	18·1
	Gas	0·49	0·72	0·23	31·9	0·89	0·85	0·04	0	1·38	1·57	0·19	12·1

scale at the interface and the amount combining with oxygen at the surface of the scale. Increases in nickel content or oxidation under less severe conditions raise the number and size of metal particles embedded in the scale; these also disrupt the diffusive path of iron through the oxide and therefore have an effect similar to that of porosity. Clearly, factors favouring metal particles must therefore diminish porosity if the total cross-section of the oxide columns which permit diffusion of iron is to remain the same. Hence the reason for the observed decrease in porosity with rising nickel content or in less oxidizing atmosphere is the increase in the amount of metal in the scale which tends to balance the porosity.

Nevertheless, metal particles and pores in the oxide are not completely identical in their effects. Porosity reduces the amount of iron diffusing through the scale to the amount reacting at the surface or the amount entering the oxide at the interface. The latter will depend on the amount of oxygen diffusing inward. If oxygen reaches the interface only as a constituent diffusing through the oxide lattice, any decrease in the effective cross-section available for diffusion would reduce the amount of oxygen diffusing through the scale in proportion to its effect on the amount of iron. However, the pores are filled with oxygen at the dissociation pressure of the surrounding oxide and oxygen can pass through them in the gaseous state. There is no experimental basis for speculations on the relative rates of travel of oxygen atoms through the oxide lattice and the pores, but the overall effect of porosity is to cut down the amount of iron diffusing through the scale while permitting oxygen to diffuse inwards. With metal particles the position is reversed. They prevent the passage of oxygen in any form but they are in equilibrium with the surrounding oxide and it is possible for iron to dissociate from the metal lattice and to enter the oxide. Again, no estimate can be made of the relative rates of travel of iron atoms through the two phases. The principal effect of the metal particles is to reduce the amount of oxygen diffusing through the scale and thus to diminish the rate of oxidation.

A change in atmosphere tending towards less severe oxidation will favour the formation of metal particles at the expense of porosity; this agrees with the experimental findings. Nickel favours the formation of metal particles by forming a metallic phase which can co-exist with wüstite of higher oxygen concentrations than pure iron. The presence of these stable metal particles leads to a decrease in porosity and a reduction in the amount of oxygen diffusing through the scale so that the rate of scaling falls slightly. This will lead to a further increase in the amount of metal embedded in the scale at the expense of porosity.

The furnace atmosphere determines the partial pressure of oxygen at the surface of the scale. If this exceeds the dissociation pressure of ferric oxide a layer of this phase will form on the surface to the scale; at lower partial pressures only magnetite will be found covering the wüstite that forms the main body of the scale. In any case the composition on both sides of the wüstite layer will be fixed, by the magnetite on the outside and by saturation with metal near the core. Thus variation in furnace atmosphere within the very wide limits which permit the formation of higher oxides will not affect the rate of diffusion of oxygen through the scale. For a wide range of oxygen concentrations, the atmosphere has relatively little influence on the structure.[3] At high partial pressures of oxygen a steep gradient of oxygen dissociation pressures across the scale may lead to the solution of the outermost metal particles and their precipitation in the filigree close to the interface, so that a coherent nickel-rich metal layer is deposited on the core. At low partial pressures of oxygen, perhaps those corresponding to the disappearance of the ferric oxide layer and the formation of a crystalline scale surface,[2] the absorption of oxygen at the surface of the scale decreases until it becomes slower than the diffusion of oxygen through the scale. The diffusion of a smaller quantity at unaltered speed implies a reduction in the cross-section available for the diffusion of oxygen; there is some reduction in porosity and an increase in the amount of metal in the scale. Since less oxygen diffuses inward the amount of iron diffusing outward is also reduced, and some porosity persists in spite of the presence of metal in the scale. The controlling rate in the parabolic oxidation of a metal is the rate of diffusion of the more slowly

Table IV

EXPERIMENTAL RESULTS

Specimen	Treatment	Inner Layers		Outer Layers		Total Scale	
		Density, g/cm³	Porosity, %	Density, g/cm³	Porosity, %	Density, g cm³	Porosity, %
Mild steel	8 h, 1180° C, electric furnace	5·35	47·8	5·24	17·5	5·27	27·8
	8 h, 1180° C, electric furnace + 5 h, 1180° C, gas furnace	...	...	...	...	5·63	20·3
1½% Ni	Electric furnace	5·79	47·9	5·31	1·5	5·44	20·9
	Gas furnace	5·64	15·9	5·30	19·1	5·46	17·3
3% Ni	Electric furnace	5·50	48·8	5·13	0	5·21	18·1
	Gas furnace	5·10	31·9	5·37	0	5·27	12·1

migrating ions through the oxide lattice. When the partial pressure of oxygen in the atmosphere is so low that the absorption of oxygen is slower than the diffusion of oxygen through the scale, the controlling rate is no longer a diffusion rate and it would be reasonable to expect a sharp drop in the rate of oxidation and deviations from the parabolic law. Equations for oxidation rates do not really apply to the fairly thick scale layers considered in this work. A decrease in the rate of oxidation does occur but is masked because considerable quantities of unoxidized metal are entangled in the scale, so that measurements of scale thickness and weight loss show no sharp drop in oxidation; measurements of weight-gain in the formation of thick scales might be of considerable interest.

Under conditions of weak oxidation, metal particles appear in the scale even on mild steel.[3] It is suggested on the basis of the present results that they are formed when oxygen diffuses through the oxide lattice faster than it is absorbed at the surface. As oxygen diffuses away from a particular volume of scale and is not replenished by the arrival of more oxygen from the surface, the oxide dissociates and metal is precipitated. Austenite containing nickel is in equilibrium with wüstite of higher dissociation pressure,[4] so that the effect of nickel in the steel is to increase the partial pressure of oxygen at which metal particles can form. The function of reducing the cross-section available to the diffusion of oxygen is fulfilled by all metal particles whether they are formed by precipitation or entrapment, and accounts for the presence of metal particles entangled with the scale in preference to two sharply separated layers.

CONCLUSION

It should now be possible to give a brief account of the process of formation of the scale structure in the oxidation of a nickel steel under fairly weakly oxidizing conditions.

At the beginning, before distinct layers of various oxides are formed, relatively severe oxidation at the surface leads to uniform oxidation of iron and nickel. As the scale grows thicker the nickel oxide in the original layer is reduced back and nickel particles are precipitated. In all further scaling two mechanisms operate side by side. The scale within the boundaries of the original specimen consists of wüstite which cannot hold nickel in stable solution. There will be a tendency for nickel to diffuse away from the advancing interface, for iron to join the wüstite lattice in preference to nickel. At the same time many nickel atoms will be caught up in the advancing wüstite lattice and thus enter into transient solution, precipitating at suitable nuclei. In effect there will be a ' partition ' of nickel, some dissolving in the scale, some diffusing away. The thicker the scale and the slower the rate of oxidation the less nickel atoms will be caught in the advancing oxide lattice, the more nickel will be entrapped in separate metal particles. At the same time the growth of oxide globules in advance of the scale interface will be more significant because the scale will advance more slowly and thus the globules will have more opportunity to grow. In this way filaments will be caught between the globules. It is these filaments in particular which are formed by preferential oxidation of iron.

As the scale advances, the nickel-bearing particles or filaments become surrounded by wüstite of gradually increasing oxygen content, which is in equilibrium with a smaller quantity of metal of higher nickel content; the nickel content of the metal at any point in the scale will depend on the dissociation pressure of the oxide in the immediate vicinity and the amount of metal will depend on the overall nickel content in the area. Thus iron is continuously dissolved from all particles in the scale, particularly from those of relatively low nickel content located between the interface and the nickel peak. Some nickel will again be forced into transient solution together with the iron which is dissolved to establish equilibrium. The nickel which goes into transient solution will be precipitated on suitable metal particles. In this way large particles very rich in nickel will form at the outside of the metal filigree. Beyond the filigree the scale may contain small particles which have been further impoverished in iron by preferential oxidation. The metal particles interrupt the diffusion path, acting in a similar way to porosity, and the latter decreases to balance the appearance of metal particles in the scale. These, however, have a greater effect than porosity in stopping the diffusion of oxygen and in consequence the rate of oxidation tends to diminish slightly with rise in nickel content.

Acknowledgment

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References

1. J. E. STEAD: *J. Iron Steel Inst.*, 1916, No. II, pp. 243–248.
2. L. B. PFEIL: *Ibid.*, 1929, No. I, pp. 501–547.
3. K. SACHS: *Metallurgia*, 1956, vol. 54, pp. 109–114.
4. K. SACHS: *J. Iron Steel Inst.*, 1957, vol. 185, pp. 348–357.
5. K. SACHS: *Metallurgia*, 1956, vol. 54, pp. 11–17.
6. K. SACHS: *J. Iron Steel Inst.*, 1956, vol. 182, pp. 305–306.
7. R. GRIFFITHS: *Ibid.*, 1934, No. II, pp. 377–384.
8. H. BÜCKLE and J. BLIN: *J. Inst. Met.*, 1951–1952, vol. 80, pp. 385–389.
9. TH. HEUMANN and A. KOTTMANN: *Z. Metallkunde*, 1953, vol. 44, pp. 139–154.
10. A. DRAVNIEKS and H. J. MCDONALD: *J. Electrochem. Soc.*, 1948, vol. 34, pp. 139–150.

The Low-temperature Impact Properties of Cast Steel

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SYNOPSIS

The object of the work was to provide data on the low-temperature properties of steel castings as produced commercially. The steels examined were supplied by seven different foundries in the form of either keel-block or clover-leaf type test castings, and were of the following types: low-carbon, medium-carbon, 1½% Mn, 1½% Mn–Mo, 1¼% Cr–Mo, 3% Cr–Mo, 4% Ni, 1½% Ni–Cr–Mo, and 2½% Ni–Cr–Mo.

Both Charpy **V**-notch and Charpy keyhole tests were carried out over a range of temperatures on steels in various conditions of heat-treatment, and the **V**-notch impact transition curves were drawn. Hardness tests were also made at subzero temperatures.

In the case of the carbon steels, the superior impact properties of normalized material, as compared with fully annealed material, and the advantage of maintaining a low carbon and high manganese content were demonstrated. The effect of tempering the quenched low- and medium-alloy steels to successively higher tensile levels was to lower the maximum impact value, and to raise the transition temperature. The importance of avoiding temper brittleness was demonstrated, and attention was drawn to the practical importance of obtaining a fully-hardened structure. 1359

THAT SOME STEELS become brittle at low temperatures was recognized at an early date. During the second world war, the serious failure of a number of ships, while at sea or motionless at the dockside, led to an intensification of the studies on brittle fracture. Many examples of catastrophic failures in structures other than ships have been given[1] and excellent reviews of the phenomenon of brittle fracture have recently appeared.[2, 3, 4, 5] The properties of steels required for use at low temperatures has become a subject of wide significance, extending into temperature ranges below those experienced climatically.

So far as steel castings are concerned, low-temperature properties are becoming of increasing importance, particularly in relation to the following fields of application:

(i) Oil-refinery plant, where refrigeration equipment used for gas liquefaction frequently operates at temperatures below −100° C
(ii) Ordnance, where castings may be used in equipment designed for service in arctic conditions
(iii) Aircraft, where flight in the stratosphere or in polar regions makes it essential for aircraft castings to have satisfactory properties down to temperatures in the region of −70° C.

It was apparent from the literature that most of the available data relating to the low-temperature properties of steel castings were mainly of U.S. origin.[6, 7, 8, 9] In view of differences which exist between U.S. and British practices, it was considered desirable that data on steel castings of British origin should be made available. The aim of the present work was therefore to obtain data on the low-temperature properties of carbon, low- and medium-alloy steel castings as produced commercially in this country.

The following types of steel were selected for investigation: low-carbon, medium-carbon, 1½% Mn, 1½% Mn–Mo, 1¼% Cr–Mo, 3% Cr–Mo, 4% Ni, 1½% Ni–Cr–Mo, 2½% Ni–Cr–Mo.

The Charpy **V**-notch was used for the main test, but a limited number of tests were also made using the keyhole-notch.

PROVISION AND HEAT-TREATMENT OF TEST MATERIAL

Test material was supplied by seven member companies of the British Steel Castings Research Association in the form of either keel-block or clover-leaf type test castings (*see* Figs. 1, 2, and 3), six such castings being supplied from each of three separate heats of steel. Particulars of all the test material, in so far as steelmaking, deoxidation practice, and form of test-block casting are concerned, are given in Tables I and II. In all cases test blocks were received in the as-cast condition, with feeder heads removed. It will be noted that the low- and medium-carbon steels from supplier *B*, and the 1¼% Cr–Mo steel *K*, were supplied with the clover-leaf blocks already sectioned, i.e. as separate clover leaves. Chemical

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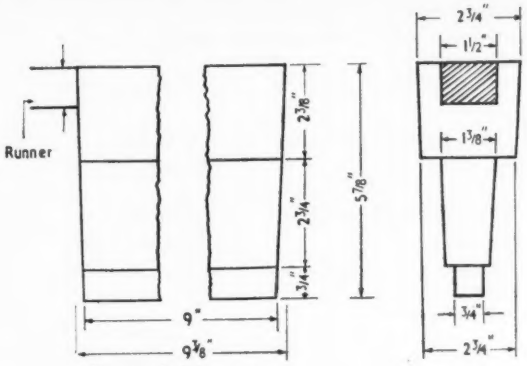


Runner is 1 in. across

Fig. 1—Keel-block test casting (supplier A)

analyses of each heat of steel are given in Tables III and IV.

Each of the suppliers gave details of the heat-treatments they would normally give to the steel provided. These treatments were applied to an appropriate number of test blocks in each case. Alternative treatments were then given, which in the case of the carbon steels were applied with a view to comparing impact properties in the annealed, normalized, annealed and normalized, and quenched and tempered conditions. Details of these treatments are given in Table V, from which it may be seen that repeat treatments were carried out in the case of low-carbon steels from supplier *C*, to determine whether there was any variation in impact properties in the normalized condition, according to whether the clover-leaf material was heat-treated in the form of divided or undivided clusters.

The heat-treatments applied to the low- and medium-alloy steels are summarized in Table VI, from which it will be seen that the material was in each case tempered to one of four nominal tensile levels. The measure of success achieved in attaining these levels is indicated by the hardness values given in the right-hand columns of the Table. Before the test pieces were machined, however, hardness was checked by making Brinell impressions on a portion of the test-block casting, suitably ground to remove the casting surface and decarburized layer.

To allow comparison of impact properties to be made in different conditions of heat-treatment, the

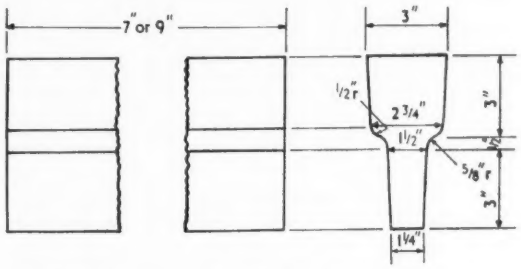


Fig. 2—Keel-block test casting (other suppliers)

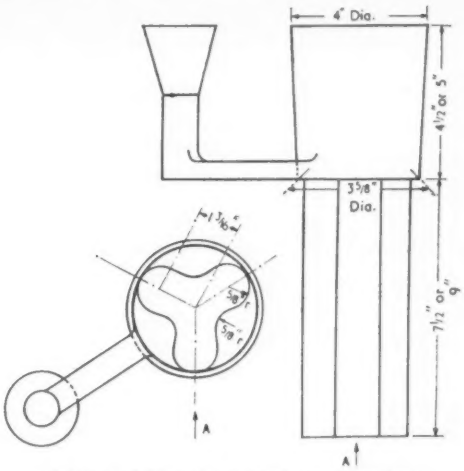


Fig. 3—Clover-leaf block test casting

following treatments were applied to certain low- and medium-alloy steels:

(i) Normalizing and tempering, and quenching and tempering
(ii) Normalizing and tempering, and double normalizing and tempering
(iii) Air cooling from tempering temperature, and water quenching from tempering temperature
(iv) Quenching, and tempering to different hardness levels.

PREPARATION OF TEST RESULTS

Twelve Charpy **V**-notch impact test pieces* were prepared from each heat of steel in each condition of heat-treatment. In addition, three or four specimens were prepared with the standard A.S.T.M. keyhole notch,† but, in this case, only from material which had received the supplier's recommended heat-treatment.

* B.S. 131: 1933, Beam-type 10-mm square test piece
† A.S.T.M. E23–47T type B specimen

Table I
MANUFACTURING PARTICULARS OF CARBON STEELS

All steels made by basic electric process

Steel, % carbon	Supplier	De-oxidation finishing practice	Type of test casting provided
0·15–0·20	A	Si–Mn 15 lb/ton Fe–Mn Fe–Si 15 lb/ton Al 2½ lb/ton to ladle	Keel-block test coupons (9 in. × 3½ in. × 1½ in.)
	B	Fe–Mn Fe–Si Al 2½ lb/ton to ladle	Clover-leaf test coupons, divided cluster (7 in. × 1½ in. dia.)
	C	Al 2 lb/ton to ladle	Clover-leaf test blocks (9 in. long)
0·30–0·35	B	Fe–Mn Fe–Si Al 2½ lb/ton to ladle	Clover-leaf test coupons, divided cluster (7 in. × 1½ in. dia.)
	C	Al 2 lb/ton to ladle	Clover-leaf test blocks (9 in. long)

Table II

MANUFACTURING PARTICULARS OF MEDIUM- AND LOW-ALLOY STEEL

Steel	Material Code	Steelmaking Process	Deoxidation and Finishing Additions, lb/ton	Form of Block
1½% Mn	F	Tropenas converter	FeSi-3, Al-2, FeTi-2, CaSiMn-1½, all to ladle	8½ in. keel
	G	Basic high-frequency	Al-2·24 (0·1%) to ladle	8½ in. clover-leaf
1½% Mn–Mo	H	Tropenas converter	FeSi-3, Al 2, FeTi-2, CaSiMn-1½, all to ladle	8½ in. keel
	I	Basic electric arc	Al-1½, CaSi-2, to ladle	9 in. clover-leaf
	J	Basic electric arc	Two additions of FeSi; Al-2, to ladle	8½ in. clover-leaf
1¼% Cr–Mo	K	Basic electric arc	FeSi, FeMn; Al-2½ to ladle	7 in. clover leaves (divided from block)
	L	Basic high-frequency	FeSi-13, FeMn-10½; Al-4 to ladle	9½ in. keel
1½% Ni–Cr–Mo	M	Basic electric arc	Two additions of FeSi; Al-2 to ladle	8½ in. clover-leaf
2½% Ni–Cr–Mo	N	Basic high-frequency	Heats 1 and 3: CaSi-7·8 (0·35%) to ladle; Heat 2: CaSiMn-10 to ladle	8½ in. clover-leaf
4% Ni	O	Basic high-frequency	FeSi-15, FeMn (C free)-11½; Al-3½ to ladle	9½ in. keel
3% Cr–Mo	P	Basic high-frequency	FeSi-6, FeMn-6; Al-3 to ladle	9½ in. keel
	Q	Basic high-frequency	Heat 1: CaSi-10; Heats 2 and 3: CaSi-7·8 (0·35%) to ladle	8½ in. clover-leaf

All the notches were machined in a direction parallel to the nearest casting surface (i.e. in general, at right-angles to the columnar crystals).

In the case of keel-block castings, the **V**-notch test pieces were machined from the bottom ' slice ' of each keel, which allowed for the preparation of six test pieces. Therefore, two keel blocks were required for the preparation of twelve test pieces. It was necessary to remove the keyhole-notch test pieces from the ' slice ' adjacent to the bottom. This was considered to be satisfactory, because the total height of metal removed from the bottom of the keel block did not exceed 1 in., and therefore no variation in properties due to changes in structure was to be expected. The small ' secondary keel ' on test-block castings from supplier *A* (*see* Fig. 1) was used to provide keyhole-notch test pieces, while in the case of all clover-leaf test castings the third leaf was used.

In order to establish whether impact values were influenced by the position of the test pieces in relation to the casting, all the Charpy test pieces were appropriately stamped to indicate their position.

IMPACT TESTING PROCEDURE

All the test pieces, with the exception of those obtained from carbon steels from supplier *B*, were tested on a Mohr and Federhaff Charpy machine, having a striking energy of 30 kg-m and a striking velocity of 5·3 m/s. The **V**-notch test pieces were broken over a range of temperature sufficiently wide to permit construction of the full transition curves,* which in most cases involved heating some of the test pieces. The methods used to obtain the desired testing temperatures are given in the Appendix.

* i.e. up to a temperature which gave 100% ductile fracture, and down to a temperature which gave approximately 5 ft-lb

The test pieces obtained from steels supplied by foundry *B* were tested on an Avery Charpy machine, having a striking energy and velocity equivalent to that of the Mohr and Federhaff. **V**-notch tests on these particular steels were carried out over a restricted temperature range, which allowed construction of the lower end of the transition curves only.

From the resulting **V**-notch impact transition curves for steels heat-treated to the supplier's recommendation, the temperatures likely to be associated with a 15 ft-lb keyhole impact energy were estimated. Approximately three keyhole-notch specimens from each steel were then broken at temperatures in the neighbourhood of these estimated values, the exact

Table III

CHEMICAL ANALYSES OF CARBON STEELS

Steel, % carbon	Supplier	Heat no.	Chemical analysis, % C	Si	Mn	S	P
0·15–0·20	A	1	0·15	0·38	0·75	0·032	0·032
		2	0·20	0·38	0·63	0·034	0·019
		3	0·195	0·48	0·83	0·025	0·043
	B	1	0·16	0·38	0·91	0·013	0·019
		2	0·17	0·45	0·87	0·016	0·018
		3	0·18	0·49	0·95	0·019	0·020
	C	1	0·19	0·47	0·67	0·015	0·037
		2	0·16	0·38	0·60	0·018	0·036
		3	0·17	0·44	0·77	0·018	0·027
0·30–0·35	B	1	0·30	0·30	0·81	0·026	0·015
		2	0·31	0·43	0·97	0·025	0·010
		3	0·30	0·48	0·75	0·019	0·018
	C	1	0·32	0·47	0·66	0·015	0·035
		2	0·34	0·46	0·61	0·019	0·030
		3	0·32	0·34	0·72	0·016	0·033

Table IV—CHEMICAL ANALYSES OF LOW- AND MEDIUM-ALLOY STEELS

Steel	Material code	Heat no.	Chemical analysis, %							
			C	Si	Mn	S	P	Ni	Cr	Mo
1½% Mn	F	1	0·24	...	1·80	0·022	0·044	...	...	...
		2	0·21	0·25	1·52	0·028	0·043	...	...	...
		3	0·23	0·20	1·64	0·024	0·056	...	...	...
	G	1	0·25	0·39	1·55	0·043	0·022	0·29	0·09	...
		2	0·25	0·34	1·55	0·046	0·022	0·31	0·09	...
		3	0·23	0·34	1·45	0·045	0·024	0·27	0·08	...
1½% Mn–Mo	H	1	0·28	...	1·38	0·027	0·046	...	...	0·27
		2	0·30	...	1·38	0·030	0·044	...	...	0·28
		3	0·31	...	1·38	0·020	0·047	...	...	0·25
	I	1	0·25	0·46	1·33	0·014	0·027	0·65	0·47	0·34
		2	0·26	0·48	1·38	0·012	0·024	0·83	0·56	0·42
		3	0·23	0·42	1·29	0·013	0·026	0·70	0·42	0·36
	J	1	0·30	0·31	1·43	0·015	0·017	0·77	0·49	0·33
		2	0·31	0·41	1·46	0·020	0·016	0·65	0·46	0·33
		3	0·31	0·43	1·35	0·021	0·021	0·83	0·40	0·29
1¼% Cr–Mo	K	1	0·30	0·36	0·67	0·016	0·019	...	1·73	0·51
		2	0·28	0·28	0·73	0·014	0·022	...	1·70	0·53
		3	0·31	0·27	0·91	0·012	0·024	...	1·71	0·59
	L	1	0·30	0·31	0·51	0·041	0·022	0·18	1·33	0·45
		2	0·30	0·34	0·48	0·038	0·023	0·18	1·34	0·46
		3	0·31	0·23	0·51	0·036	0·023	0·21	1·29	0·45
1½% Ni–Cr–Mo	M	1	0·31	0·34	0·66	0·026	0·017	1·54	0·64	0·28
		2	0·32	0·40	0·76	0·015	0·013	1·65	0·69	0·32
		3	0·27	0·27	0·69	0·013	0·020	1·50	0·60	0·29
2½% Ni–Cr–Mo	N	1	0·33	0·34	0·74	0·013	0·015	2·65	0·74	0·47
		2	0·34	0·27	0·51	0·013	0·020	2·82	0·74	0·42
		3	0·29	0·43	0·70	0·014	0·017	2·40	0·59	0·40
4% Ni	O	1	0·08	0·33	0·58	0·038	0·019	3·90	0·06	...
		2	0·09	0·32	0·55	0·030	0·020	3·96	0·17	...
		3	0·10	0·28	0·60	0·030	0·020	3·89	0·11	...
3% Cr–Mo	P	1	0·16	0·22	0·55	0·033	0·024	0·25	3·48	0·34
		2	0·17	0·29	0·60	0·032	0·022	0·21	3·25	0·45
		3	0·16	0·28	0·39	0·042	0·022	0·25	3·33	0·46
	Q	1	0·24	0·42	0·44	0·020	0·019	0·12	3·23	0·51
		2	0·27	0·41	0·74	0·032	0·013	0·08	3·20	0·44
		3	0·26	0·51	0·76	0·032	0·022	0·09	3·45	0·49

temperature associated with 15 ft-lb being in each case interpolated from the results obtained.

RESULTS OF IMPACT TESTS

V-notch impact transition and fracture appearance transition curves were drawn for each one of three heats from each steel, in each condition of heat-treatment. Since it is not practicable to reproduce all the curves here (276 were drawn), the results are, in general, given in histogram form. 'Transition temperatures' were determined from the curves by means of four arbitrary criteria, selected because of their

Table V—HEAT-TREATMENTS APPLIED TO CARBON STEELS

Steel, % carbon	Supplier	Supplier's usual treatment	Alternative treatments		Ruling section at time of treatment*
0·15–0·20	A	7 h 950° C A.C.	...	...	1½ in. (keel coupon)
	B	4 h 920° C A.C.	...	...	1½ in. (divided cluster)
	C	2 h 900° C A.C.	2 h 920° C F.C. to 550° C	2 h 920° C F.C. to 550° C ¼ h 900° C A.C.	1¾ in. (undivided cluster)
		2 h 900° C A.C.	...	...	1½ in. (divided cluster)
0·30–0·35	B	4 h 920° C A.C.	...	4 h 920° C A.C. ¼ h 870° C W.Q. 1 h 500° C A.C.	1½ in. (divided cluster)
	C	2 h 935° C F.C. to 350° C	2 h 920° C A.C.	2 h 935° C F.C. to 350° C ¼ h 870° C A.C.	1¾ in. (undivided cluster)

* Diameter of largest inscribed circle

Table VI

HEAT-TREATMENTS APPLIED TO LOW- AND MEDIUM-ALLOY STEELS AND HARDNESS VALUES OBTAINED

Steel	Material code	Heat-treatment				Nominal U.T.S. aimed at, tons/in²	Equivalent hardness, D.P.N.	Test-piece hardness, D.P.N. (50-kg load)			
		Code	Anneal, °C	Harden (°C) normalize or quench	Temperature, °C			Heat 1	Heat 2	Heat 3	Mean
1½% Mn	F	X	2 h 940°	2 h 910° A.C.	2 h 500° a.c.*	40	200	213	187	200	200
		V	2 h 940°	2 h 900° W.Q.	2 h 620° and 3 h 655° a.c.	40	200	216	210	212	213
		W	2 h 940°	2 h 900° W.Q.	2 h 620° and 3 h 655° w.q.	40	200	212	199	210	207
	G	X	2 h 950°	2 h 910° W.Q.	2 h 660° w.q.*	40	200	184	189	186	187
		S	2 h 950°	2 h 910° W.Q.	2 h 550° w.q.	50	240	218	217	222	219
1½% Mn–Mo	H	S	2 h 940°	2 h 910° W.Q.	3 h 690° a.c.	40	200	213	213	215	214
		X	2 h 940°	2 h 910° W.Q.	2 h 620° and 3 h 655° a.c.*	50	240	225	232	232	230
		Y	2 h 940°	2 h 910° W.Q.	2 h 550° a.c.	60	285	284	298	301	294
	I	X	2 h 935°	2 h 900° A.C.	3 h 655° a.c.*	50	240	228	241	223	231
		W	2 h 935°	2 h 900° and 2 h 900° A.C.	3 h 650° a.c.	50	240	235	248	231	238
		Y	2 h 935°	2 h 900° W.Q.	3 h 605° w.q.	60	285	287	300	280	289
		T	2 h 935°	2 h 900° W.Q.	1½ h 550° w.q.	75	355	342	354	335	341
	J	X	8 h 950°	6 h 900° W.Q.	6 h 610° w.q.*	60	285	270	268	271	269
1¼% Cr–Mo	K	X	4 h 950°	½ h 920° A.C.	4 h 700° f.c.*	40	200	188	190	189	189
		V	3 h 950°	2 h 900° W.Q.	4 h 690° a.c.	50	240	225	227	223	225
	L	X	3 h 950°	2 h 900° W.Q.	4 h 690° a.c.*	50	240	239	232	230	234
		S	3 h 950°	2 h 900° W.Q.	3 h 620° a.c.	60	285	298	292	296	295
		T	3 h 950°	2 h 900° W.Q.	3 h 550° a.c.	75	355	375	370	365	370
1½% Ni–Cr–Mo	M	S	8 h 900°	6 h 870° O.Q.	6 h 670° w.q.	50	240	233	242	240	238
		X	8 h 900°	6 h 870° O.Q.	6 h 600° w.q.*	60	285	267	282	249	266
		T	8 h 900°	6 h 870° O.Q.	1 h 550° w.q.	75	355	301	324	314	313
2½% Ni–Cr–Mo	N	S	2 h 950°	2 h 880° O.Q.	3 h 675° and 1 h 680° a.c.	50	240	264	256	248	256
		X	2 h 950°	2 h 880° O.Q.	2 h 640° a.c.*	60	285	291	280	283	285
		T	2 h 950°	2 h 880° O.Q.	2 h 560° a.c.	75	355	377	363	357	366
4% Ni	O	V	3 h 950°	2 h 850° W.Q.	3 h 650° a.c.	40	200	201	200	204	202
		X	3 h 950°	2 h 850° W.Q.	3 h 650° w.q.*	40	200	202	215	213	210
		S	3 h 950°	2 h 850° W.Q.	½ h 550° w.q.	50	240	226	216	222	221
3% Cr–Mo	P	X	3 h 950°	3 h 900° O.Q.	3 h 655° a.c.*	50	240	235	227	223	228
	Q	X	2 h 950°	2 h 900° O.Q.	6 h 650° and 3 h 700° a.c.*	50	240	211	213	221	215
		S	2 h 950°	2 h 900° O.Q.	3 h 640° a.c.	60	285	281	284	280	282

* Supplier's recommended heat-treatment
A.C. (air cool), W.Q. (water quench), O.Q. (oil quench), from hardening temperature
a.c. (air cool), w.q. (water quench), f.c. (furnace cool), from tempering temperature

Table VII

INFLUENCE OF COOLING RATE FROM THE NORMALIZING TEMPERATURE ON THE LOW-TEMPERATURE IMPACT PROPERTIES OF LOW-CARBON STEELS

Supplier	Form of material as normalized		Mean* temperature (°C) to give			
	Clover leaf	Ruling section	10 ft-lb (V-notch)	15 ft-lb (V-notch)	Mean energy	50% fibrous fracture
B	Divided	1½ in.	−86	−62	...	−11
C	Divided	1¼ in.	−68	−53	+10	+10
	Undivided	1¼ in.	−57	−45	+ 8	+25

* Mean value of three heats in each case

Table VIII

CARBON STEELS. TRANSITION TEMPERATURES AND LOWEST TEMPERATURES AT WHICH IMPACT ENERGIES OF 10 ft-lb AND 15 ft-lb CAN BE OBTAINED

After application of supplier's recommended heat-treatments*

Steel, % carbon	Supplier	Heat no.	Temperature (° C) to give				
			10 ft-lb (V-notch)	15 ft-lb (keyhole notch)	15 ft-lb (V-notch)	Mean energy	50% fibrous fracture
0·15–0·20	A	1	−70	−80	−50	0	0
		2	−40 mean −56	−60 mean −73	−25 mean −35	+ 5 mean +8	+15 mean +15
		3	−58	−80	−30	+20	+30
	B	1	−92	−115	−75	...	−12†
		2	−82 mean −86	−105 mean −104	−55 mean −62	...	−10† mean −11
		3	−84	−100	−55	...	−10†
	C	1	−59	−85	−45	+15	+30
		2	−55 mean −57	−80 mean −85	−45 mean −45	0 mean +8	+20 mean +25
		3	−57	−90	−45	+10	+25
0·30–0·35	B	1	−35	−39	−19	...	+ 4
		2	−46 mean −46	−50 mean −50	−26 mean −26	...	− 2 mean +4
		3	−57	−61	−32	...	+ 9
	C	1	+ 5	0	+19	+40	+70
		2	+14 mean +11	+10 mean +7	+30 mean +25	+55 mean +52	+70 mean +72
		3	+14	+10	+25	+60	+75

* See Table V
† Extrapolated

frequent use in the U.S. and British literature on brittle fracture and low-temperature impact testing, and also because of the need for specific criteria for comparison purposes. These were:

(i) The 10 ft-lb impact level
(ii) The 15 ft-lb impact level
(iii) The ' mean energy,' i.e. the temperature at which the energy absorbed is the mean of the energies corresponding to the toe and the peak of the impact energy transition curve
(iv) The 50% fibrous (ductile), 50% brittle (cleavage) fracture level.

In all cases, the mean transition temperature of three heats is that recorded in the histograms. Not more than two transition temperatures were indicated on any one histogram, for the sake of clarity. As mentioned previously, keyhole-notch transition curves were not determined, only sufficient test pieces being broken to allow the 15 ft-lb keyhole temperature to be assessed for material heat-treated according to the supplier's recommendation.

The results of low-temperature impact tests made on the carbon steels are summarized in Figs. 4 and 5,

Table IX

CARBON STEELS. COMPARISON OF PROPERTIES IN ANNEALED AND IN NORMALIZED CONDITIONS (SUPPLIER C)

Steel, % carbon	Treatment	Heat no.	Temperature (° C) to give			
			10 ft-lb (V-notch)	15 ft-lb (V-notch)	Mean energy	50% fibrous fracture
0·15–0·20	Annealed*	1	−22	−12	+28	+40
		2	−20 mean −26	−12 mean −16	+25 mean +24	+35 mean +38
		3	−35	−25	+20	+40
	Normalized‡ (undivided leaves)	1	−59	−45	+15	+30
		2	−55 mean −57	−45 mean −45	0 mean +8	+20 mean +25
		3	−57	−45	+10	+25
	Normalized‡ (divided leaves)	1	−64	−48	+10	+ 8
		2	−67 mean −69	−52 mean −53	+ 5 mean +10	+ 2 mean +10
		3	−75	−58	+14	+21
0·30–0·35	Annealed†	1	+ 5	+19	+40	+70
		2	+14 mean +11	+30 mean +25	+55 mean +52	+70 mean +72
		3	+14	+25	+60	+75
	Normalized‡	1	−11	+ 6	+46	+55
		2	−16 mean −18	+ 2 mean +1	+33 mean +41	+43 mean +48
		3	−26	− 6	+44	+45

* 2 h 920° C, F.C. to 550° C
† 2 h 935° C, F.C. to 350° C
‡ 2 h 920° C, A.C.

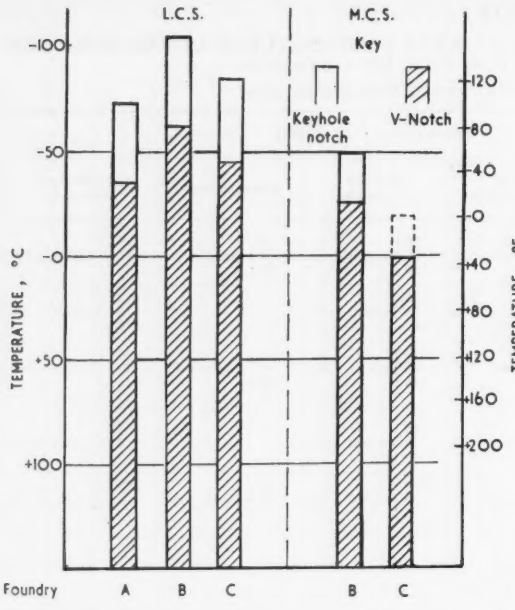


Fig. 4—Comparison of mean temperatures to give 15 ft-lb (V and keyhole notch) for carbon steels in the normalized condition

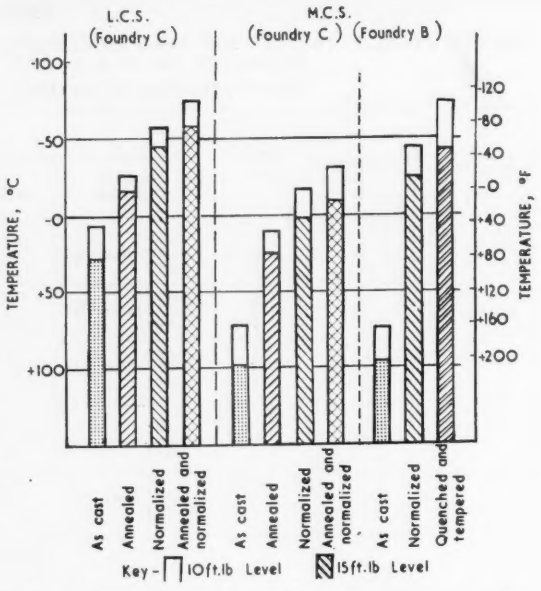


Fig. 5—Comparison of mean temperatures to give 15 ft-lb (V-notch) for carbon steels in different conditions of heat-treatment

while more complete results are given in tabular form in Tables VII–XI. Figure 4 compares the mean temperatures to give 15 ft-lb (both keyhole and **V**-notch) in the normalized condition, while the influence of heat-treatment on material tested using **V**-notch test pieces is illustrated by Fig. 5. Typical impact transition curves for a low- and a medium-carbon steel, in different conditions of heat-treatment, are shown in Fig. 6. The microstructures associated with these curves are shown in Fig. 7.

The results of low-temperature impact tests made on the low- and medium-alloy steels are summarized in Figs. 8, 9, and 10, while more complete results are given in Tables XII–XV. The results are grouped according to the desired nominal tensile levels. Figure 8 summarizes the effect of type of heat-treatment, Fig. 9 the effect on quenched steels of tempering to different tensile levels, and Fig. 10 compares 15 ft-lb **V**-notch and keyhole-notch values.

HARDNESS TESTS

Vickers pyramidal hardness tests were made on each material in each condition of heat-treatment, at temperatures of + 20°, — 60°, and — 120° C. The

Table X

CARBON STEELS. COMPARISON OF PROPERTIES IN THE ANNEALED AND NORMALIZED CONDITION WITH THOSE IN THE QUENCHED AND TEMPERED CONDITION

Steel, % carbon	Supplier	Treatment	Heat no.	Temperature (° C) to give			
				10 ft-lb (V-notch)	15 ft-lb (V-notch)	Mean energy	50%-fibrous fracture
0·15–0·20	C	Annealed and normalized*	1	−72	−50	+ 6	+15
			2	−72 mean −75	−58 mean −58	− 2 mean +3	+ 5 mean +8
			3	−80	−65	+ 5	+ 3
0·30–0·35	C	Annealed and normalized†	1	−28	−10	+40	+46
			2	−38 mean −32	−10 mean −10	+30 mean +34	+35 mean +40
			3	−30	−10	+32	+40
	B	Quenched and tempered‡	1	−72	−40	−22	−24
			2	−68 mean −76	−40 mean −45	−25 mean −27	−20 mean −26
			3	−88	−56	−35	−35

* 2 h 920° C, F.C. to 550° C, ½ h 900° C, A.C.
† 2 h 935° C, F.C. to 350° C, ½ h 870° C, A.C.
‡ 4 h 920° C, ½ h 870° C, W.Q., 1 h 500° C, A.C.

Table XI

CARBON STEELS. TRANSITION TEMPERATURES AND LOWEST TEMPERATURES AT WHICH IMPACT ENERGIES OF 10 ft-lb AND 15 ft-lb CAN BE OBTAINED IN THE AS-CAST CONDITION

Steel, % carbon	Supplier	Heat no.	Temperature (° C) to give			
			10 ft-lb (V-notch)	15 ft-lb (V-notch)	Mean energy	50% fibrous fracture
0·15–0·20	A	1	−10	+ 5	+ 55	+ 70
		2	+30	+ 50	+ 70	+ 70
		3	+50	+ 70	+105	+120
			mean +23	mean +42	mean +77	mean +87
	B	1	−45	− 26	...	+ 43*
		2	− 2	+ 8	...	+ 42*
		3	+44	+ 60	...	+100
			mean −1	mean +14		mean +62
	C	1	+16	+ 35	+ 75	+ 95
		2	+10	+ 30	+ 60	+ 80
		3	− 4	+ 20	+ 90	+ 90
			mean +77	mean +28	mean +75	mean +88
0·30–0·35	B	1	+65	+ 94	...	+100
		2	+75	+ 94	...	+110
		3	+80	+100	...	+140*
			mean +73	mean +96		mean +117
	C	1	+85	+105	+115	+115
		2	+75	+100	+115	+120
		3	+56	+ 90	+110	+120
			mean +72	mean +98	mean +113	mean +118

* Extrapolated

tests were carried out on the fractured Charpy test pieces, the same specimen from each heat being used for tests at all three temperatures. The results are given in Tables XVI–XIX, where the figures quoted represent the mean of three closely agreeing impressions. The small divergences between the hardness values given at + 20° C and those given in Table VI are mainly due to the latter being representative of a number of test pieces taken from each heat. In general, the values obtained from test pieces representing the three heats from any one material exhibited similar relationships to one another at each

Table XII

LOW- AND MEDIUM- ALLOY STEELS. TRANSITION TEMPERATURES AND LOWEST TEMPERATURES AT WHICH IMPACT ENERGIES OF 10 ft-lb AND 15 ft-lb CAN BE OBTAINED

Material tempered to 40 tons/in² tensile level

Steel	Material code	Heat-treatment (*see* Table VI)		Heat no.	Temperature (° C) to give				
					10 ft-lb (V-notch)	15 ft-lb (keyhole notch)	15 ft-lb (V-notch)	Mean energy	50% fibrous fracture
1½% Mn	F	X	Normalized and tempered (a.c.)	1	−50	−52	−28	+ 8	+25
				2	−50	−40	−30	+ 2	+15
				3	−45	−40	−20	+ 8	+30
					mean −48	mean −44	mean −26	mean +6	mean +23
		V	Quenched and tempered (a.c.)	1	−56	...	−35	+ 5	+ 4
				2	−58	...	−38	− 9	− 8
				3	−40	...	−22	− 2	+ 3
					mean −51		mean −32	mean −2	mean 0
		W	Quenched and tempered (w.q.)	1	−88	...	−68	−30	−32
				2	−80	...	−60	−25	−26
				3	−70	...	−50	−18	− 8
					mean −79		mean −59	mean −24	mean −22
	G	X	Quenched and tempered (w.q.)	1	−68	−77	−50	−24	−16
				2	−72	−75	−50	−26	−37
				3	−56	− 8 approx.*	−38	−28	−14
					mean −65	mean −76	mean −46	mean −26	mean −22
1½% Mn–Mo	H	S	Quenched and tempered (a.c.)	1	−83	...	−68	−36	−27
				2	−109	...	−72	−38	−34
				3	−115	...	−78	−26	−13
					mean −102		mean −73	mean −33	mean −25
1¼% Cr–Mo	K	X	Normalized and tempered (f.c.)	1	−30	−46	−15	+35	+50
				2	−34	−50	−20	+30	+50
				3	−34	−64	−20	+35	+40
					mean −33	mean −53	mean −18	mean +33	mean +47
4% Ni	O	X	Quenched and tempered (w.q.)	1	−82	above zero†	−56	−60	−47
				2	−100	−80	−80	−73	−67
				3	−87	above zero†	−63	−55	−41
					mean −90		mean −66	mean −63	mean −52
		V	Quenched and tempered (a.c.)	1	−64	...	−43	−52	−32
				2	−100	...	−74	−61	−53
				3	−95	...	−68	−57	−51
					mean −86		mean −62	mean −57	mean −45

* Extrapolated value of 15 ft-lb keyhole-notch temperature; mean value of heat nos. 1 and 2 plotted in Fig. 10
† Extrapolation not attempted. Value of heat no. 2 plotted in Fig. 10

Table XIII

LOW- AND MEDIUM-ALLOY STEELS. TRANSITION TEMPERATURES AND LOWEST TEMPERATURES AT WHICH IMPACT ENERGIES OF 10 ft-lb AND 15 ft-lb CAN BE OBTAINED

Material tempered to 50 tons/in² tensile level

Steel	Material code	Heat-treatment (*see* Table VI)		Heat no.	Temperature (° C) to give				
					10 ft-lb (V-notch)	15 ft-lb (keyhole notch)	15 ft-lb (V-notch)	Mean energy	50% fibrous fracture
1½% Mn	G	S	Quenched and tempered (w.q.)	1	−70	...	−36	−32	−30
				2	−80 mean	...	−46 mean	−29 mean	−38 mean
				3	−32 −61	...	−8 −30	−22 −28	−38 −35
1½ %Mn–Mo	H	X	Quenched and tempered (a.c.)	1	−88	−73	−68	−20	−30
				2	−88 mean	−56 mean	−64 mean	−35 mean	−15 mean
				3	−116 −97	−84 −71	−78 −70	−43 −33	−45 −30
	I	X	Normalized and tempered (a.c.)	1	−40	−66	−22	+30	+45
				2	−32 mean	−30 mean	−12 mean	+45 mean	+50 mean
				3	−72 −48	−84 −60	−52 −29	+20 +32	+35 +43
		W	Double normalized and tempered (a.c.)	1	−36	...	−16	+28	+12
				2	−44 mean	...	−20 mean	+30 mean	+22 mean
				3	−84 −55	...	−60 −32	+8 +22	+8 +14
1¼% Cr–Mo	K	V	Quenched and tempered (a.c.)	1	−120	...	−103	−49	−55
				2	−110 mean	...	−91 mean	−46 mean	−51 mean
				3	−130 −120	...	−105 −100	−58 −51	−64 −57
	L	X	Quenched and tempered (a.c.)	2	−80	−30	−66	−66	−69
				3	−94 mean	−56 mean	−76 mean	−70 mean	−72 mean
					−84 −86	−50 −45	−63 −68	−57 −64	−61 −67
1½% Ni–Cr–Mo	M	S	Quenched and tempered (w.q.)	1	−122	...	−98	−76	−72
				2	−133 mean	...	−100 mean	−78 mean	−63 mean
				3	−108 −121	...	−88 −95	−50 −68	−54 −63
2½% Ni–Cr–Mo	N	S	Quenched and tempered (a.c.)	1	−160	...	−120	−76	−100
				2	−170 mean	...	−142 mean	−98 mean	−106 mean
				3	−144 −158	...	−123 −128	−78 −87	−77 −94
4% Ni	O	S	Quenched and tempered (w.q.)	1	−60	...	−26	−47	−40
				2	−110 mean	...	−77 mean	−64 mean	−46 mean
				3	−94 −88	...	−72 −58	−59 −57	−56 −47
3% Cr–Mo	P	X	Quenched and tempered (a.c.)	1	−66	−62	−52	−32	−29
				2	−61 mean	−60 mean	−51 mean	−36 mean	−49 mean
				3	−70 −66	−62 −61	−53 −52	−34 −34	−42 −40
	Q	X	Quenched and tempered (a.c.)	1	−120	−119	−105	−56	−56
				2	−100 mean	−124 mean	−88 mean	−53 mean	−56 mean
				3	−73 −99	−52 −98	−60 −84	−26 −45	−26 −46

temperature. Furthermore, the increase in hardness associated with each reduction in temperature appeared to be little influenced by the steel or its condition of heat-treatment.

The carbon steels, with room-temperature hardnesses between 140 and 270 D.P.N., showed on the average an increase of 12·8 D.P.N. units when the temperature was decreased to − 60° C, and a further decrease of 29·7 D.P.N. units when the temperature was reduced to − 120° C. The low- and medium-alloy steels, with room-temperature hardnesses between 185 and 435 D.P.N., showed an increase of 16·9 D.P.N. units when the temperature was decreased to − 60° C, and a further increase of 30·7 D.P.N. units when the temperature was reduced to − 120° C.

Room-temperature hardness tests were made on test pieces removed from the ends and centre of the keel-block castings, and from the bottom, middle, and top of the clover-leaf blocks, to determine whether position influenced hardness. No significant variation in hardness was found. In addition, when the impact test figures were examined, any differences in impact value between test pieces removed from the same test-block casting and tested at the same temperature could not be consistently related to their original position. It was therefore concluded that the material used was reasonably homogeneous.

MICROSCOPICAL EXAMINATION

Metallographic examination of the steels, in the condition in which they were subjected to impact testing, was made on representative sections. Examination in the unetched state indicated the presence of a normal quantity of non-metallic inclusions, with satisfactory distribution of the sulphides.

DISCUSSION

It is emphasized that this investigation was not planned or conducted primarily to compare one steel composition with another. To enable such a comparison to be drawn, it would have been necessary to prepare all the test material under conditions where variables such as the steelmaking process, deoxidation

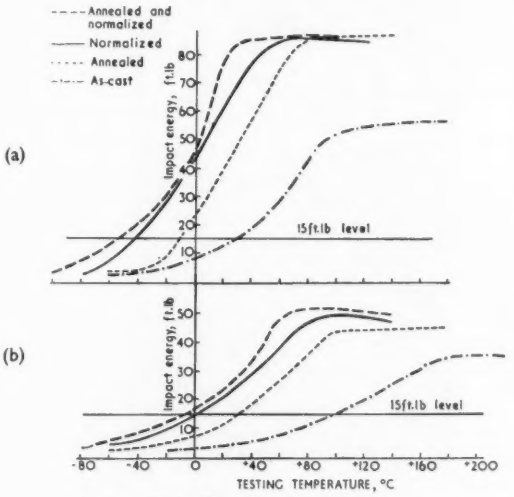
Table XIV

LOW- AND MEDIUM-ALLOY STEELS. TRANSITION TEMPERATURES AND LOWEST TEMPERATURES AT WHICH IMPACT ENERGIES OF 10 ft-lb AND 15 ft-lb CAN BE OBTAINED

Material tempered to 60 tons/in² tensile level

Steel	Material code	Heat-treatment (*see* Table VI)		Heat no.	Temperature (° C) to give				
					10 ft-lb (V-notch)	15 ft-lb (keyhole-notch)	15 ft-lb (V-notch)	Mean energy	50% fibrous fracture
	H	Y	Quenched and tempered (w.q.)	1	−65	...	−36	−23	−45
				2	−80 mean	...	−42 mean	−18 mean	−25 mean
				3	−105 −83	...	−54 −44	−38 −26	−55 −42
1½% Mn–Mo	I	Y	Quenched and tempered (a.c.)	1	−108	...	−95	−50	0
				2	−82 mean	...	−65 mean	−25 mean	+15 mean
				3	−112 −101	...	−98 −86	−45 −40	−35 −7
	J	X	Quenched and tempered (w.q.)	1	−130	−120	−108	−76	−80
				2	−120 mean	−80 mean	−106 mean	−86 mean	−78 mean
				3	−140 −130	−110 −103	−120 −111	−80 −81	−76 −78
1¼% Cr–Mo	L	S	Quenched and tempered (a.c.)	1	−77	...	−48	−66	−37
				2	−76 mean	...	−48 mean	−56 mean	−52 mean
				3	−90 −81	...	−62 −53	−67 −63	−58 −49
1½% Ni–Cr–Mo	M	X	Quenched and tempered (w.q.)	1	−108	−88	−86	−62	−84
				2	−140 mean	−110 mean	−104 mean	−78 mean	−82 mean
				3	−100 −116	−80 −93	−72 −87	−34 −58	−36 −61
2½% Ni–Cr–Mo	N	X	Quenched and tempered (a.c.)	1	−116	−106	−100	−66	−80
				2	−136 mean	−132 mean	−120 mean	−96 mean	−92 mean
				3	−136 −129	−124 −121	−122 −114	−76 −79	−68 −80
3% Cr–Mo	Q	S	Quenched and tempered (a.c.)	1	−65	...	−50	−23	−22
				2	−38 mean	...	−23 mean	− 6 mean	+ 8 mean
				3	−20 −41	...	− 6 −26	+ 8 −7	+13 0

practice, and impurity content (sulphur and phosphorus) were each under control. This was not possible at the time and in any case the purpose of the investigation was to establish low-temperature property levels which could be obtained in commercial practice, rather than those obtainable in steels manufactured under strictly comparable conditions. For this reason, the comparisons between different types of steels, and in particular those drawn in Fig. 9, should be interpreted with the greatest care.



(*a*) Low-carbon steel (*b*) Medium-carbon steel

Fig. 6—Comparison of V-notch transition curves for carbon steels in various conditions of heat-treatment (supplier C, heat No. 2, in each case)

By the use of the 15 ft-lb (keyhole and V-notch) temperature as a basis for assessing the relative performance of the different steels in different conditions of heat-treatment, there is no wish to imply that the steels are necessarily suitable for service at the temperatures associated with this arbitrary energy level. From a metallurgical point of view, fracture appearance is perhaps of greater significance, and should be considered when assessing the lowest temperature at which a particular steel may be regarded as serviceable.

The V-notch test piece was used for the main series of tests, because of the sharper ductile–brittle transition normally exhibited when using this type of notch. Furthermore, it is widely used in the United Kingdom for experimental work, and there is evidence in the literature that it is becoming increasingly favoured in the U.S.A. In the present work no Izod tests were made, and it is pointed out that although the V-notch used in the Charpy test piece is identical to that used in the Izod, and the transition curves obtained from either test follow the same sort of relationship, the results are not wholly consistent with one another and no direct correlation should be attempted.

Carbon Steels

The impact properties in the 'as-cast' condition of both the low- and medium-carbon steels were inferior and more variable than those obtained on heat-treated material. It is clear that a normalizing

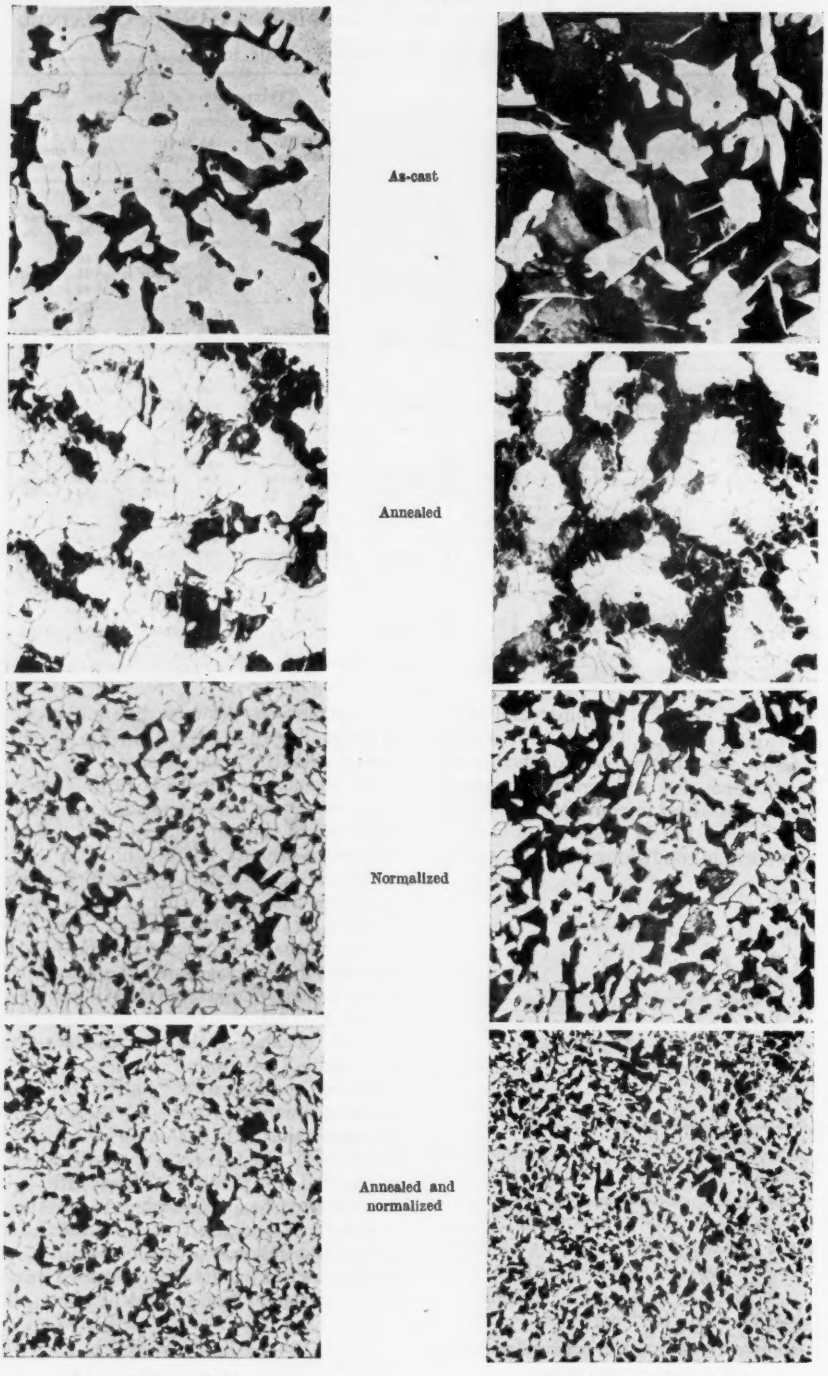


Fig. 7—Microstructures corresponding to transition curves in Fig. 6 × 120

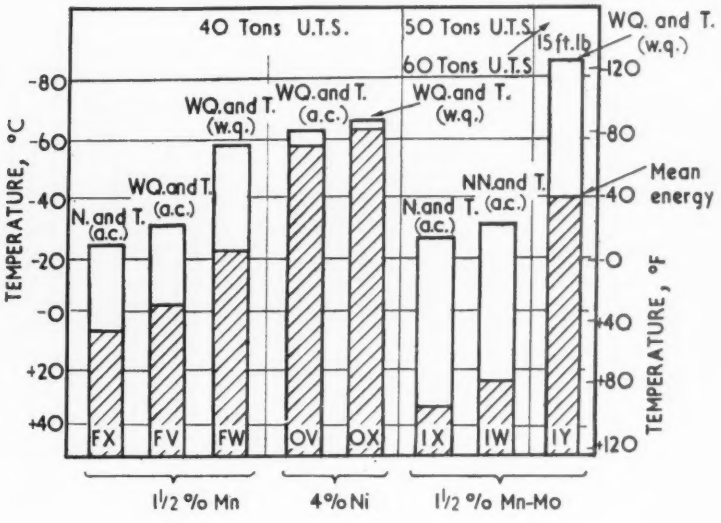


Fig. 8—Comparison of mean temperatures to give 15 ft-lb and mean energy transition temperatures (both V-notch) for low- and medium-alloy steels in different conditions of heat-treatment

treatment is superior to a full annealing treatment, the degree of improvement being on the average a reduction of 25–30° C in the transition temperature. In practice the extent of this improvement will depend on the sectional thickness of the material, as the thickness controls the cooling rate in air. It is to be expected that the difference between the properties of annealed and normalized material would be less in castings of heavier section. Nevertheless, routine mechanical tests are usually carried out on test blocks similar to those employed in this investigation.

The difference in sectional thickness must be taken into consideration in Fig. 4 when comparing the results obtained on the low-carbon steels from suppliers *B* and *C*. To investigate the influence of this variable, one test block from each heat of low-carbon steel *C* was sectioned before heat-treatment, to provide separate test leaves. These were then normalized by the same treatment as that previously applied to the un-sectioned material. The test results are compared in Table VII, from which it will be noted that, although the single (divided) clover leaves show slightly better properties than the complete block (undivided) on account of their faster cooling rate, the

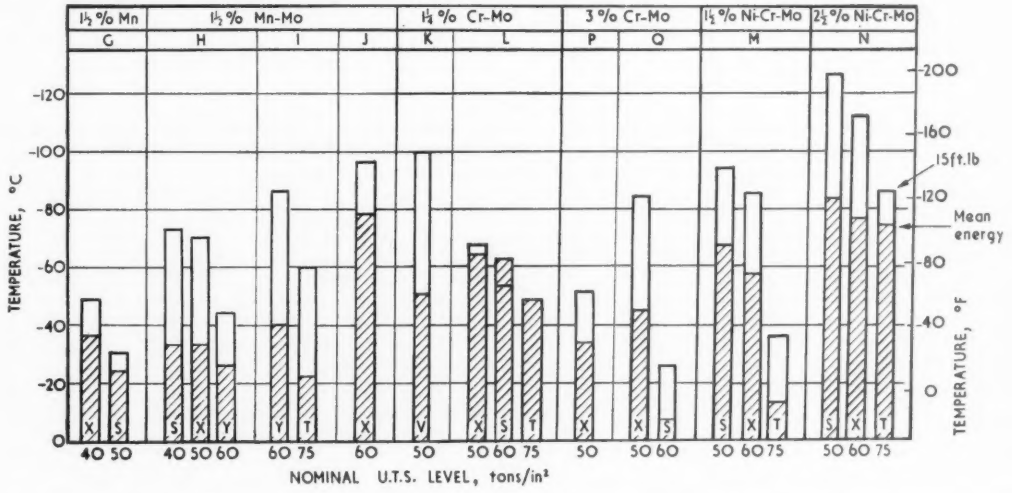


Fig. 9—Comparison of mean temperatures to give 15 ft-lb and mean energy transition temperatures (both V-notch) for low- and medium-alloy steels quenched and tempered to different tensile levels

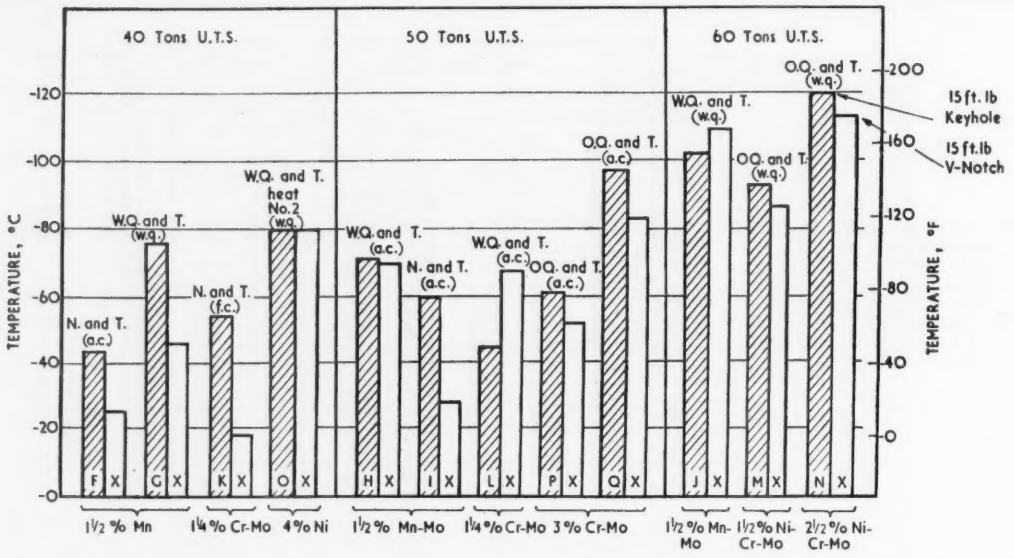


Fig. 10—Comparison of mean temperatures to give 15 ft-lb keyhole notch and 15 ft-lb V-notch, for low- and medium-alloy steels in the condition of heat-treatment recommended by the supplier

improvement is not of sufficient magnitude to account for the difference in the results obtained.

The annealing and normalizing process improves low-temperature impact properties in both the low- and medium-carbon steels, while annealing and quenching and tempering of the medium-carbon steels gives an even greater improvement. The effect of double normalizing was not investigated for the carbon steels, but the progressive enhancement of low-temperature impact properties in going from the annealed condition, through the normalized and the annealed and normalized, to the quenched and tempered condition, demonstrates the importance of a grain-refining heat-treatment.

The generally superior properties of steels from supplier *B* are evident, and a number of factors probably contribute to this. Apart from unrecorded process differences, the high manganese and low phosphorus contents of steels provided by this supplier may be observed (*see* Table III). The influence of phosphorus content on impact properties, however, is not clear from the present data, because of the number of process variables operating. A factor of greater significance is undoubtedly the Mn/C ratio, a high value favouring good impact figures, as demonstrated in Fig. 11. This general observation has been noted by other investigators.[10, 11] From the data available in the present work, it cannot be concluded that the Mn/C ratio is of any fundamental significance; its importance probably lies in the fact that carbon

Table XV

LOW- AND MEDIUM-ALLOY STEELS. TRANSITION TEMPERATURES AND LOWEST TEMPERATURES AT WHICH IMPACT ENERGIES OF 10 ft-lb AND 15 ft-lb CAN BE OBTAINED

Material Tempered to 75 tons/in² Tensile Level

Steel	Material code	Heat-treatment (*see* Table VI)		Heat no.	Temperature (°C) to give			
					10 ft-lb (V-notch)	15 ft-lb (V-notch)	Mean energy	50% fibrous fracture
1½% Mn–Mo	I	T	Quench and temper (w.q.)	1	−76	−56	−29	−40
				2	−71	−42	−10	−20
				3	−113	−81	−27	−34
				mean	−87	−60	−22	−31
1¼% Cr–Mo	L	T	Quench and temper (a.c.)	1	−35	+60	−37	−60
				2	−28	+180	−50	−60
				3	−60	0	−60	−60
				mean	−41	+80	−49	−60
1½% Ni–Cr–Mo	M	T	Quench and temper (w.q.)	1	−70	−38	−14	−20
				2	−124	−70	−40	−10
				3	−54	−4	+14	+32
				mean	−83	−37	−13	+1
2½% Ni–Cr–Mo	N	T	Quench and temper (a.c.)	1	−106	−72	−71	−49
				2	−148	−105	−94	−64
				3	−102	−84	−60	−70
				mean	−119	−87	−75	−61

Table XVI

ROOM- AND LOW-TEMPERATURE HARDNESS OF CARBON STEELS, IN THE AS-CAST AND NORMALIZED CONDITIONS

Steel, % carbon	Supplier	Heat no.	Low temperature hardness, D.P.N. (50-kg load)					
			As-cast			Normalized (see Table V)		
			+20° C	−60° C	−120° C	+20° C	−60° C	−120° C
0·15–0·20	A	1	142	155	179	142	157	177
		2	150	158	189	150	163	200
		3	157	169	192	162	177	203
	B	1	151	167	195	144	165	191
		2	175	193	219	157	172	197
		3	203	223	249	176	193	219
	C	1	165	170	205	158 (161)*	172 (170)*	197 (200)*
		2	150	157	193	146 (151)	156 (158)	191 (188)
		3	155	168	194	159 (162)	170 (175)	194 (197)
0·30–0·35	B	1	209	224	250	165	188	209
		2	225	246	274	191	209	242
		3	217	236	263	173	192	213
	C	1	199	206	241	192	202	241
		2	197	208	241	188	202	226
		3	181	191	220	185	296	230

* Figures in brackets refer to hardness of specimens taken from material normalized in the form of clover-leaf divided blocks

raises the transition temperature and manganese lowers it, each independently of the other.

Low- and Medium-Alloy Steels

Illustrations of the advantage of quenching and tempering over normalizing and tempering in the low-alloy steels are given in Fig. 8, which demonstrate the practical importance of fully hardening to secure optimum low-temperature impact properties. In the case of steel *I*, although a direct comparison between *IX* and *IY* is unjustified because of their different tensile levels, the improvement shown in quenching (*IY*) would have been even greater had the material been tempered to 50 tons/in² tensile level. That there is only a small advantage to be gained in double normalizing and tempering the 1½% Mn–Mo steel *I*, as compared to single normalizing and tempering, is also demonstrated in Fig. 8.

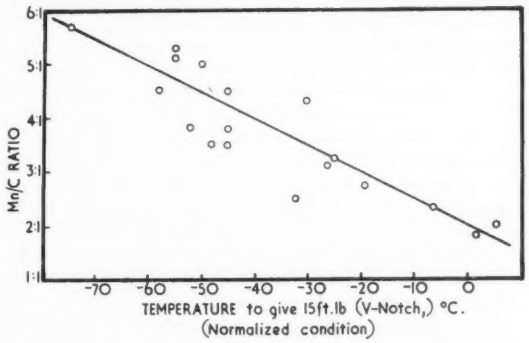


Fig. 11—Variation of 15-ft-lb (V-notch) temperature with the Mn/C ratio, for normalized carbon steels

It is generally acknowledged that certain steels are susceptible to temper brittleness and that even if tempering is carried out at temperatures above a critical range, slow cooling through this range will result in temper embrittlement. The results in Fig. 8 show that water quenching the 1½% Mn steel after tempering (*FW*) develops low-temperature properties which are superior to air cooling after tempering (*FV*). A similar but smaller improvement was exhibited by the 4% Ni steel, as illustrated by the treatments *OX* and *OV*. This result is to be expected as nickel alone is reported to have a smaller temper-embrittling influence than manganese.[12]

Table XVII

ROOM- AND LOW-TEMPERATURE HARDNESS OF CARBON STEELS, IN THE ANNEALED, ANNEALED AND NORMALIZED, AND QUENCHED AND TEMPERED CONDITIONS

Steel, % carbon	Supplier	Heat no.	Heat-treatment (see Table V)	Hardness, D.P.N. (50-kg load)		
				+20° C	−60° C	−120° C
0·10–0·15	C	1	Annealed	149	159	190
		2		140	149	178
		3		149	161	187
	C	1	Annealed and normalized	157	170	199
		2		146	156	190
		3		160	169	196
0·30–0·35	B	1	Quenched and tempered	230	242	277
		2		236	255	283
		3		266	279	335
	C	1	Annealed	174	188	218
		2		173	177	218
		3		165	180	210
	C	1	Annealed and normalized	191	198	228
		2		187	197	228
		3		182	189	226

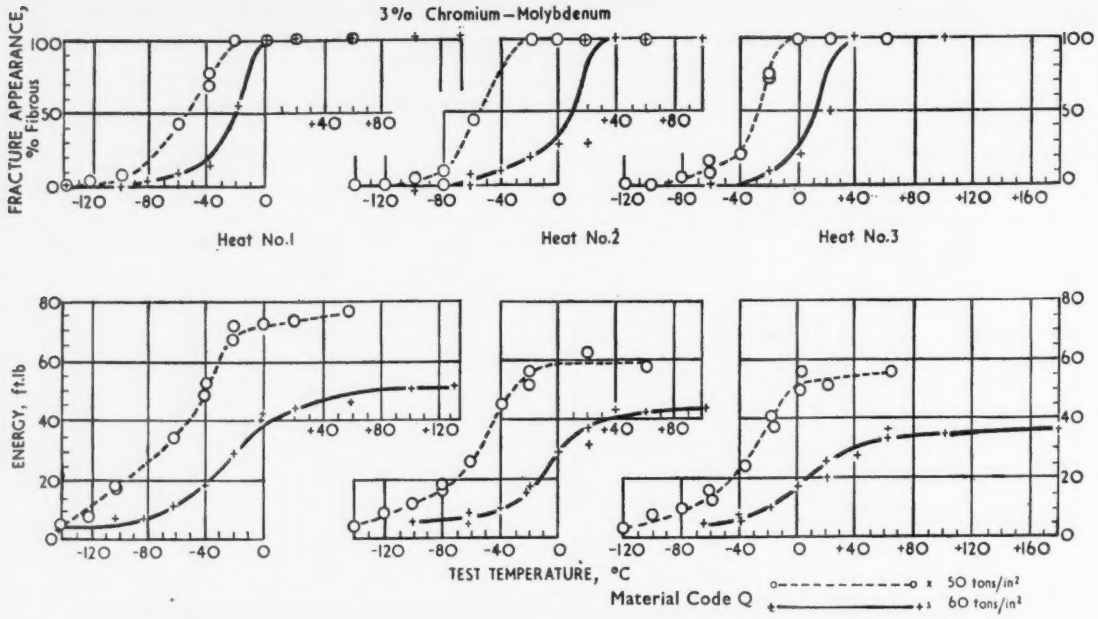


Fig. 12—Impact and fracture appearance transition curves for 3% Cr–Mo steel Q

Attention is drawn to the superior 15 ft-lb values of steel *K* when quenched and tempered to a nominal 50 tons/in² tensile level. This steel was supplied in the form of divided clover leaves (*see* Table II); hence heat-treatment was carried out on a smaller sectional thickness compared to the other low- and medium-alloy steels. The faster cooling rate during quenching therefore may have influenced the impact test results.

Figure 9 illustrates primarily the effect on low-temperature properties of tempering low- and medium-alloy steels to different tensile levels. (The 4% Ni steel *O* has been omitted since the heat-treatments did not produce any significant differences in hardness, as may be observed in Table VI.) It will be seen from this diagram that, in general, transition temperatures are raised by increasing the tensile level (hardness). Examination of the full transition temperature curves shows that, at the higher testing temperatures, the maximum impact values are reduced by increasing the tensile level. These effects are well illustrated by the transition curves of the 3% Cr–Mo steel *Q* in Fig. 12, which are fairly representative of all the impact-energy/transition curves. However, in general the fracture-appearance/transition curves are less consistent, as in a few instances pairs of curves appear to have been transposed. These differences are in most cases only slight and could have arisen from difficulties in estimating the proportions of fibrous and brittle fracture occurring in the broken test pieces.

In an attempt to assess, for each steel, the influence of changing hardness, the shift of the 50% fibrous fracture transition temperature was expressed in terms of an increase in hardness of 50 points (D.P.N.). No consistent relationship was apparent, the shift in temperature sometimes being in the direction of an increase, and sometimes a decrease. Such an analysis of the impact-energy/transition curves would have been complicated by the changes in maximum impact values. To obviate this difficulty a measurement was made of the area bounded by the curves themselves and the lines joining the lowest temperature points on each curve where 100% fibrous fracture and 100% brittle fracture occurred. Again, no consistent relationship between change in hardness and the area represented by the shift was apparent. Other attempts to relate the shift of either the impact-energy or the fracture-appearance transition curves to a causative factor (e.g. hardness or tempering temperature) were unsuccessful. It therefore appears that if a transition curve of a quenched and tempered steel is known, the transition curve resulting from the use of a different tempering temperature cannot at present be predicted.

A more detailed examination of Figs. 8 and 9 shows that in the case of the 4% Ni steel *O*, the 1¼% Cr–Mo steel *L*, and the 3% Cr–Mo steel *P*, the differences between the temperatures associated with the 15 ft-lb and mean energy levels are in general less than in the case of the remaining steels. The transition curves of these steels show that their maximum energy levels are low, and in the case of steels *L* and *P* much lower than the comparable steels *K* and *Q* respectively. The low maximum-impact values have the effect of reducing the mean energy levels, and the temperatures associated with them. For this reason, mean energy transition temperatures probably form a less satisfactory basis for comparison than do the temperatures associated with the 15 ft-lb level.

The low maximum energy levels of steels *O*, *P*, and *L* is possibly to be explained by their relatively high sulphur contents (*see* Table IV), although it should be noted that steel *G*, which also has a high sulphur

content, does not exhibit this particular feature. It may also be noted that the 1½% Mn–Mo steel *J*, treatment *X*, shows superior properties to either steel *I*, treatment *Y*, or steel *H*, treatment *Y* (*see* Fig. 9). While this may be due to some other process variable, it is pointed out that steel *J* received a heat-treatment in which the annealing, hardening, and tempering times (8, 6, and 6 h respectively) were considerably in excess of those used for the other steels. An investigation of the influence of methods of steelmaking and deoxidation practice, heat-treatment variables, the effect of impurities, residual elements and gases, on the low-temperature properties of steel castings may well form the basis for future work.

CONCLUSIONS

The main object of the work was to provide data on the low-temperature impact properties of cast steels as produced commercially. To present the data, several arbitrary criteria were used, and it is not wished to imply that a steel should necessarily be regarded as suitable for service down to the temperatures associated with these arbitrary levels.

Using these criteria, the results are summarized diagrammatically in Figs. 4, 5, 8, 9, and 10, and more complete data are given in Tables VIII–XV. Within the limits of the experimental work described, the following conclusions also emerge.

Carbon Steels

(1) The annealed *and* normalized material gave low-temperature impact properties superior to the normalized material.

(2) The normalized material gave low-temperature impact properties superior to the annealed material.

(3) The ' as-cast ' material gave low-temperature impact properties which were both inferior to and more variable than material in the heat-treated condition.

(4) A high Mn/C ratio favoured the development of the optimum low-temperature impact properties.

Low- and Medium-Alloy Steels

(5) In the case of the 1½% Mn and the 1½% Mn–Mo steels, quenching and tempering gave low-temperature impact properties superior to normalizing and tempering.

(6) Double normalizing and tempering the 1½% Mn–Mo steel did not result in any marked improvement over single normalizing and tempering.

(7) In the case of the 1½% Mn steel, which was susceptible to temper brittleness, the advantage of quenching over normalizing was only significant when quenching from the tempering temperature was also applied. Only small advantage was gained by quenching the low-carbon 4% Ni steel from the tempering temperature.

(8) The general effect of decreasing the tempering temperature (increasing tensile level) of quenched steels was twofold,

(i) to lower the maximum impact value, and

(ii) to raise the transition temperature.

(9) Strictly speaking, the work described does not permit the low-temperature impact properties of the various alloy steels to be compared on the basis of chemical composition *per se*. However, the development of superior properties by steels in the fully hardened and tempered condition implies that optimum results can be secured in steel castings for low-temperature service only if the alloy content is sufficient to ensure that full hardening is obtained with the quenching facilities available.

Table XVIII

LOW-TEMPERATURE HARDNESS OF 1½% Mn AND 1½% Mn–Mo STEELS IN DIFFERENT CONDITIONS OF HEAT-TREATMENT

Steel	Material code	Heat-treatment code	Heat no.	Hardness, D.P.N. (50-kg load)		
				+20° C	−60° C	−120° C
1½% Mn	F	X	1	216	228	253
			2	186	201	225
			3	199	214	239
		V	1	215	235	266
			2	204	217	257
			3	214	234	268
		W	1	215	233	260
			2	196	217	252
			3	212	229	269
	G	X	1	192	207	232
			2	195	209	242
			3	187	199	230
		S	1	230	246	277
			2	213	229	251
			3	256	272	296
1½% Mn–Mo	H	S	1	215	231	256
			2	216	230	259
			3	216	237	261
		X	1	231	246	267
			2	238	251	281
			3	234	245	274
		Y	1	306	318	323
			2	287	294	328
			3	305	322	349
	I	X	1	231	246	273
			2	248	260	290
			3	227	238	269
		W	1	236	254	279
			2	252	271	296
			3	230	253	278
		Y	1	288	306	336
			2	299	314	349
			3	290	308	332
		T	1	347	365	399
			2	362	374	408
			3	338	355	388
	J	X	1	267	286	351
			2	272	292	325
			3	268	285	317

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On behalf of the British Steel Castings Research Association, the authors wish to record their appreciation of the help afforded by Mr. H. F. Hall of A.R.D.E., Woolwich, who undertook the low-temperature impact testing of all the low- and medium-alloy steels and part of the carbon steels, and all the low-temperature hardness testing, and the late Mr. L. Smith of Imperial Chemical Industries, Ltd., who undertook the low-temperature impact testing of part of the carbon steels. Acknowledgment is also made to Dr. L. Northcott, Deputy Chief Scientific Officer of A.R.D.E., Woolwich, and Mr. F. H. Keating,

Table XIX

LOW-TEMPERATURE HARDNESS OF 1¼% Cr–Mo, 3% Cr–Mo, 1½% Ni–Cr–Mo, 2½% Ni–Cr–Mo AND 4% Ni STEELS, IN DIFFERENT CONDITIONS OF HEAT-TREATMENT

Steel	Material code	Heat-treatment code	Heat no.	Hardness, D.P.N. (50 kg load)		
				+20° C	−60° C	−120° C
1¼% Cr–Mo	K	X	1	194	206	238
			2	196	205	235
			3	196	208	235
		V	1	225	245	275
			2	227	247	276
			3	227	245	275
	L	X	1	237	258	282
			2	233	255	281
			3	228	247	284
		S	1	301	316	351
			2	297	313	344
			3	298	312	350
		T	1	386	403	433
			2	374	393	428
			3	367	387	419
1½% Ni–Cr–Mo	M	S	1	237	254	281
			2	246	260	289
			3	224	234	264
		X	1	264	286	340
			2	289	305	340
			3	253	268	299
		T	1	310	326	365
			2	352	364	392
			3	319	334	369
2½% Ni–Cr–Mo	N	S	1	265	281	307
			2	262	280	309
			3	254	273	305
		X	1	298	323	345
			2	286	312	344
			3	287	308	344
		T	1	380	399	423
			2	365	383	414
			3	355	371	405
4% Ni	O	V	1	201	220	245
			2	202	222	249
			3	204	222	254
		X	1	208	235	253
			2	209	226	256
			3	199	220	245
		S	1	221	239	266
			2	214	229	257
			3	233	243	277
3% Cr–Mo	P	X	1	230	251	272
			2	227	248	279
			3	221	240	276
	Q	X	1	215	230	267
			2	218	236	269
			3	224	242	271
		S	1	282	300	339
			2	289	308	340
			3	280	299	366

Chief Metallurgist, Imperial Chemical Industries, Ltd., Billingham Division, who authorized the tests to be carried out in their respective laboratories.

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References

1. M. E. SHANK: "Symposium on Effect of Temperature on the Brittle Behaviour of Metals with Particular Reference to Low Temperatures," pp. 45–104, 1954, Special Technical Publ. 158, American Society for Testing Materials, Philadelphia.
2. E. R. PARKER: *Ibid.*, pp. 116–129.
3. S. L. HOYT: *Ibid.*, pp. 133–143.
4. T. S. ROBERTSON: *Iron Steel*, 1955, vol. 28, pp. 161–166.
5. C. P. OLDRIDGE: *Welding Metal Fab.*, 1955, vol. 23, pp. 55–60, 103–111.
6. C. E. SIMS and F. W. BOULGER: *Trans. Amer. Found. Soc.*, 1946, vol. 54, pp. 357–374.
7. T. N. ARMSTRONG and A. P. GAGNEBIN: *Trans. Amer. Soc. Metals*, 1940, vol. 28, pp. 1–19.
8. N. A. ZIEGLER and H. W. NORTHRUP: *Ibid.*, 1942, vol. 30, pp. 1087–1108.
9. R. W. MOFFATT: *Canad. J. Research*, 1930, vol. 2, pp. 327–340.
10. J. A. RINEBOLT and W. J. HARRIS: *Trans. Amer. Soc. Metals*, 1951, vol. 43, pp. 1175–1214.
11. W. BARR and A. J. K. HONEYMAN: *J. Iron Steel Inst.*, 1947, vol. 157, pp. 243–246.
12. A. P. TABER, J. F. THORLIN, and J. F. WALLACE: *Trans. Amer. Soc. Metals*, 1950, vol. 42, pp. 1033–1054.

APPENDIX

Method of Attaining Required Testing Temperature

The Charpy impact specimens were immersed in a liquid medium for the purpose of heating or cooling to the desired testing temperature. The vessel used for the liquid bath at all temperatures below + 100° C was a Dewar flask of 6 in. internal diameter, and 10 in. deep. Specimens were lowered into the liquid on a perforated metal tray, by means of which they were later raised to the surface and the one selected for test was transferred by tongs to the testing machine.

All specimens were held in the bath at the test temperature for at least 20 min before testing. The time interval between removal from the bath and testing did not exceed 4 s. The tongs used for handling the specimens were maintained at the bath temperature while the specimens were immersed.

The liquid media used for the various temperature ranges were:

− 196° C	liquid nitrogen
− 150° to − 80° C	*iso*-pentane with liquid nitrogen
− 75° to − 1° C	commercial alcohol with solid carbon dioxide
0° to + 95° C	water
+ 100° to + 220° C	glycerine.

When liquid nitrogen or solid carbon dioxide was used as a coolant, the addition was made a little at a time direct to the bath, which was immediately stirred. At temperatures above + 100° C the Dewar flask was replaced by a heat-insulated metal beaker. Heating was provided by an electric hotplate and an electric immersion heater.

Low temperatures were continuously indicated by a pyrometer immersed in the bath, which consisted of either a platinum resistance thermometer or a copper/constantan thermocouple. At temperatures above + 100° C bulb thermometers were used.

Similarity Criteria for Dust-deposition Tests in Models

By R. A. Granville, B.Sc., A.Inst.P., A. Sigalla, B.Sc., A.C.G.I., and Hope Lubanska

SYNOPSIS

The similarity criteria for conducting dust-deposition tests in models have been derived from four geometrically similar models and the criteria have been successfully applied to the analysis of the experimental results obtained. Their application to the conduct and interpretation of open-hearth furnace dust-deposition and flow-visualization tests is discussed. 1415

Introduction

THE USE OF TRANSPARENT MODELS with air or water as the working medium to investigate the gas-flow distribution and mixing patterns inside furnaces has steadily increased in the iron and steel industry in the U.K. Five steel companies have established laboratories that regularly employ these techniques and many others make occasional use of them. The experimental techniques are well established and the necessary similarity criteria are known.[1, 2] More recently, investigators have extended the range of model techniques to include the simulation of slag deposition and refractory wear, but these techniques are at present diverse and mainly empirical in application. Similarity criteria for conducting tests have been previously derived,[3] which are related to some of the criteria developed later in this paper, but the derivation by these authors was incomplete, lacking in rigour, and was not employed quantitatively. It is well known that the location and extent of the deposition of solid and liquid particles within the furnace and its appendages are partly functions of the particle size, therefore a derivation of the similarity criteria is required which would show the correct employment of model tests involving fluid-borne particles and would assist their quantitative interpretation. These criteria may also serve to guide and interpret the technique of flow visualization by the illumination of balsa-wood dust suspended in the model air stream.

It is the object of this report to derive the model similarity criteria for particle trajectories and deposition, and to verify their correct application.

THE EQUATIONS OF MOTION OF A PARTICLE IN A FLUID STREAM

It will be assumed that the particle is spherical and obeys Stokes' law of resistance.

Consider fixed Cartesian axes with the three directions parallel to, and in the same sense as, i, j, and k, and let the following symbols be used:

Symbol	Quantity
$u_{i,j,k}$	Particle component velocities
$v_{i,j,k}$	Fluid stream component velocities
$\gamma_{i,j,k}$	Direction cosines of the earth's gravitational field
g	Local acceleration due to gravity
L	A characteristic length of the model or flow system
D	Particle diameter
U	Particle free-falling speed in the fluid
V	A characteristic fluid velocity
μ	Absolute viscosity of the fluid
ν	Kinematic viscosity of the fluid
t	Time

Then the equations of motion of the particle are:

$$m\frac{du_i}{dt} = mg\gamma_i + 3\pi\mu D(u_i - v_i) \quad \ldots\ldots(1)$$

By substituting $U_i' = \frac{u_i}{V}$, $V_i' = \frac{v_i}{V}$, $t' = t\frac{V}{L}$ in equation (1), the following is obtained;

$$m\frac{V^2}{L}\frac{dU_i'}{dt'} = mg\gamma_i + 3\pi\mu D\, V(U_i' - V_i')$$

$$\therefore \quad \frac{dU_i'}{dt'} = \left[\frac{gL}{V^2}\right]\gamma_i + \left[\frac{3\pi\mu DL}{mV}\right](U_i' - V_i') \quad \ldots(2)$$

By substituting $F = \frac{V^2}{gL}$, and $P = \frac{mV}{3\pi\mu DL}$, the dimensionless equation (2) may be rewritten;

$$\frac{dU_i'}{dt'} = \frac{1}{F}(\gamma_i) + \frac{1}{P}(U_i' - V_i') \quad \ldots\ldots(3)$$

By substitution of the free-falling speed of the particle in the appropriate term in equation (2) it may be shown that;

$$P = \frac{UV}{gL} \quad \ldots\ldots(4)$$

For geometrically similar systems, dynamic similarity depends upon the equality of the dimensionless parameters F, P, and γ. F is the Froude number, and P will be referred to as the particle number, which has been derived by Davies and Aylward.[4] The parameter γ is a measure of the inclination

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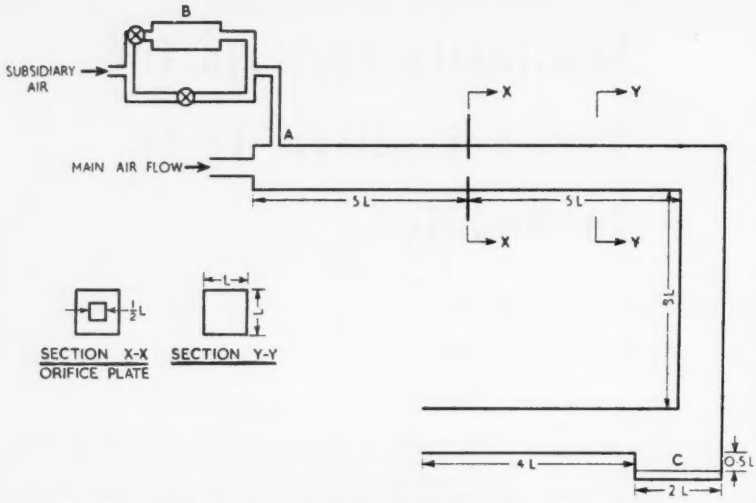


In the four models used L=1, 1·5, 2, and 3 in.; A, ½-in. diameter orifice; B, Bypass; C, Collecting tray

Fig. 1—Diagram of models

between the direction of gravity and the local direction of a streamline, and in this context similarity is ensured by arranging similar flow patterns and orientation. This depends in turn on other parameters of which the most important is the Reynolds number R of the system, where $R = VL/\nu$.

For similar solutions of equation (2), and hence for similarity in models, similar boundary conditions are also necessary. It may be shown that this requires similarity of the ratio D/L, but in most applications this ratio is extremely small and may be ignored. In addition it is necessary that the particles should be introduced into the systems at similar locations and with corresponding initial velocities. These conditions can be critical, particularly if the particles are introduced near the area of deposition, but their importance can be minimized by suitable experimental arrangement and technique.

RELATIVE INFLUENCE OF THE PARAMETERS

It is not in general possible to solve equation (3) analytically, although, as it will be shown, conclusions can be derived from an inspection of the various terms.

If F is very large, the first term on the right-hand side of equation (3) can be neglected and gravity can have little influence on the particle motion. This particular case has received detailed study by other investigators particularly in problems of aircraft icing. The resulting simplification has enabled investigation of the relative effects on particle motion caused by varying the parameter, D/L, and the study of systems where the particle may no longer obey Stokes' law of resistance.[5, 6] When F is small, however, the effect of gravitational forces on the motion of the particle can no longer be neglected, but this circumstance has so far received little attention. It will be of considerable importance in the study of particle deposition inside open-hearth furnaces or similar structures because these flow systems normally have a small Froude number.

The effect of Reynolds number R on particle motion has been studied[7] and it was found that the influence becomes progressively smaller with large Reynolds numbers.

From an inspection of the second term in equation (3) it is to be expected that as the particle number increases in size it will have a decreasing influence on the particle motion. Thus if other terms in the equation remain constant, mass collection efficiency or deposition on any selected area will tend to a limit as P increases in magnitude.

The equations and the parameters derived from them are strictly applicable only to spherical particles obeying Stokes' law of resistance. As the relative velocity between a particle and surrounding fluid increases, the resistance tends to become proportional to the square of the relative velocity. Nevertheless, if the true falling speed of a particle is employed in the calculation of P, the parameters might still be expected to provide an adequate definition of particle motion and deposition, even though they are non-spherical and their resistance to motion is not accurately defined by Stokes' law.

EXPERIMENTS

A series of experiments was planned to confirm the conclusions derived from the equations and to illus-

Table I

DUST PARTICLE CHARACTERISTICS

	Lyco-podium	French Chalk	Aluminium Powders				
Code letter	g	f	a	b	c	d	e
Mean diameter, microns	30	23	77	100	200	300	425
Calculated free-falling speed in air, cm/s	2·4	5·1	40	58	152	247	330

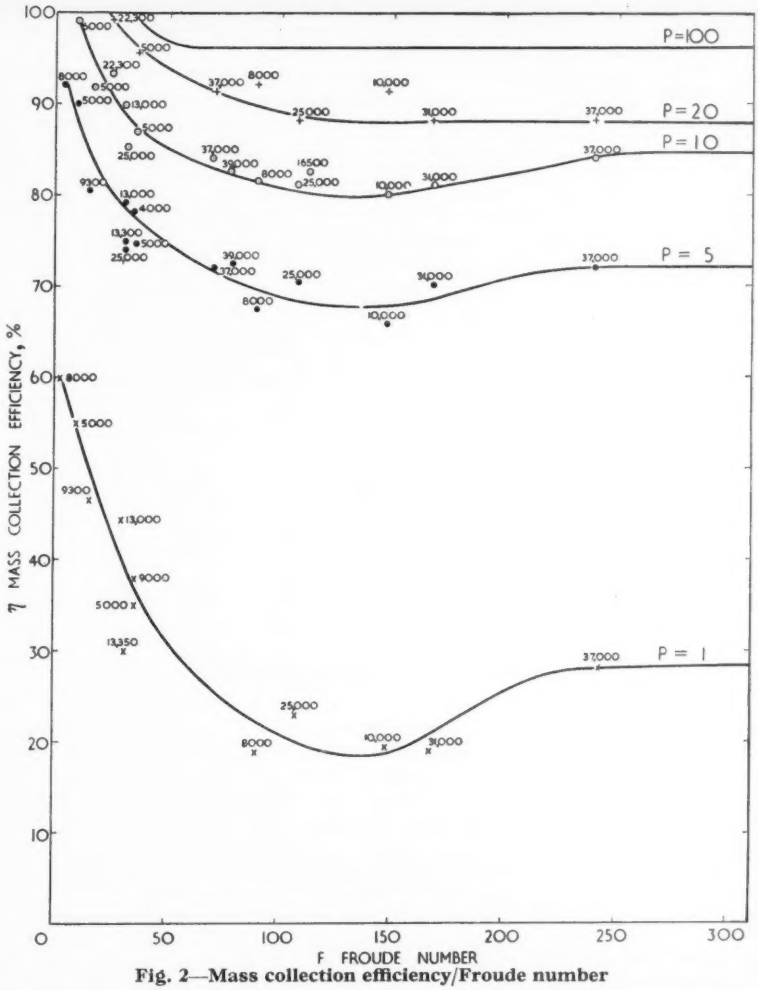


Fig. 2—Mass collection efficiency/Froude number

trate for a single geometrical system the relative importance of the previously derived parameters. Four geometrically similar models were constructed in Perspex to the design shown in Fig. 1, where L was equal to 1·0, 1·5, 2·0, and 3·0 in. Several test dusts with different mean particle diameters were prepared and their free-falling speeds were calculated.[8] Although these particles, apart from the lycopodium, were not spherical, experiment showed that their free-falling speeds were close to those of spherical particles of similar diameter and density. Particles were introduced into the main air stream through the $\frac{1}{4}$-in. diameter orifice at A by means of the bypass B. The collecting tray C was sealed to the model during tests and contained a small quantity of oil which prevented any re-entrainment of the deposited dust. This particular system was chosen since dust deposition at a right-angled bend with a vertical entrance is commonly experienced and no single parameter may be expected to control the deposition for a wide range of air velocity and dust particle size.

About 3 g of one of the various grades of dust, described in Table I, was weighed in the bypass tube which was then connected to the model. The collecting tray was also weighed. Air-flow rates through the main and subsidiary lines were adjusted to the required values and the subsidiary airflow was then diverted through the bypass so that the particles were gradually introduced in a dispersed manner into the main stream. When all the particles had been swept from the bypass, the collecting tray was removed and weighed. Mass collection efficiency was defined as the mass of dust collected in the tray, divided by the mass of dust originally placed in the bypass. The results of these tests are shown in Table II and represent the average mass collection efficiencies from a large number of determinations at discrete flow rates.

The experimental data were analysed by calculating the values of particle number, P, associated with each of the mass collection efficiencies, η, and plotting η against P or its logarithm. This resulted in one characteristic curve for each corresponding value of R and F shown in the third and fourth columns of Table II. From these curves a table of values was obtained for F and η at values of P equal to

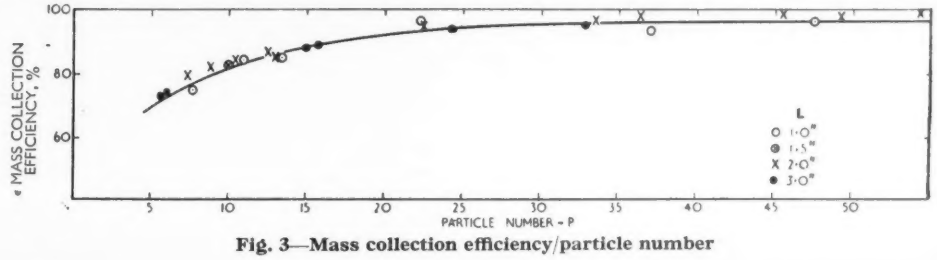


Fig. 3—Mass collection efficiency/particle number

Table II
EXPERIMENTAL RESULTS

Model	Flow Rate, ft³/min	Reynolds Number	Froude Number	Mass Collection Efficiencies %, η						
L, in.	Q	R	F	Lycopodium	French Chalk	Aluminium Powders				
				g	f	a	b	c	d	e
1	4·1	5100	36	8·7	14·5	74	...	95	95	...
	6·5	8050	91	10	19	75	84	96	96	96
	8·3	10200	148	13·5	24·3	...	85	93	97	...
1·5	11	9100	34	...	19·4	67	81	98	99	...
	6·1	5000	10·5	5	...	60	80	96	99	...
	20	16500	113	...	...	...	82	...	...	...
2	15	9330	15·1	11·5	20·5	63	72	89	94	95
	21·5	13300	31·2	13	25	70	78	...	96	95
	40	24800	108	13	28·5	75	...	95	98	98
	50	31000	168	13	28·5	79	84	...	99	99
	60	37200	242	14	32	82	87	97	99	99
	88	55000	520	16	43	85	...	...	...	...
3	20	8250	3·5	...	...	...	65	86	90	...
	40	16500	14	...	...	...	63	...	87	...
	54	22300	25·6	...	...	...	71	91	97	...
	60	25000	32	...	...	...	68	85	92	...
	90	37200	71	14	22	...	73	88	94	95
	95	39300	79	...	31	...	74	89	...	...

The reference velocity V employed in the calculation of R, F, and P, is defined by Q/L^2 in consistent units

1, 5, 10, and 20. Values of F and η for P equal to 100 were obtained for the most part by a small extrapolation of the curves. In Fig. 2 these derived data are plotted to show mass collection efficiency as a function of Froude number for discrete values of particle number. The Reynolds number for the model is given beside each of the points from which the curves were constructed.

DISCUSSION

It may be seen from Fig. 2 that for the larger values of the Froude number F and for a given particle number P, the mass collection efficiency η remains virtually constant, indicating that in this region the motion is not influenced by gravitational forces. For small values of F gravitational forces predominate, and in this part of the models assist particle collection. Between these two regions occurs another in which F and P have a combined influence which for smaller values of P causes a minimum collection of particles. The form of the collection efficiency curves (*see* Fig. 2) is a function of the particular system which was investigated, but the minima indicate that it would be a poor range in which to operate this system as a particle collecting device. As the value of P increases, and for a given F, η tends to a limiting value. This is also illustrated by data from all the models in Fig. 3 where η is shown as a unique function of P, for values of $F > 50$ and $P > 5$.

The effect of the Reynolds number is illustrated in Fig. 2 where the numbers are entered beside each experimental point. It may be seen that in the range investigated there is virtual independence of Reynolds number, since with this particular geometrical arrangement, the turbulent flow pattern changes only slightly with Reynolds number. If, however, the mean air velocities of the system were reduced to low values, the flow patterns would certainly alter and the motion and deposition of very small particles would be increasingly influenced by local forces of diffusion.[9]

If it is assumed that the relative velocity between any of the particles employed in these experiments and the air stream was of the same order as their free-falling speeds, some of the particles experienced forces which were greater than those predicted by Stokes' law, which was assumed in the analysis. Nevertheless, Figs. 1 and 2 illustrate that the derived parameters adequately described the motion of all the particles employed in these experiments.

CONCLUSIONS AND APPLICATION TO MODEL FURNACE TESTS

The analysis and experiments have shown that the Froude number F, particle number P, and similarity of flow pattern are critical. It appears from these experiments and previous investigations that the main flow pattern in model open-hearth furnaces is primarily a function of the Reynolds number R, but that approximate similarity of the main flow pattern can be achieved by some reduction of the model Reynolds number below that of the furnace. On the other hand the flow patterns near the walls of the model furnace are more likely to be affected by changes in R than those remote from it, and relaxation of Reynolds similarity is therefore not always recommended.

Simultaneous Reynolds and Froude similarity can be achieved in a system provided that,

$$\frac{L_1}{L} = \left[\frac{\nu_1}{\nu}\right]^{\frac{2}{3}}$$

where L and L_1 denote characteristic lengths in the furnace and model, and ν and ν_1 are the kinematic viscosities of the furnace gases and air. For an open-hearth furnace model using air as the working medium this implies a scale of roughly 1/7 full size. Using water as the working medium would necessitate a scale of about 1/50 full size, and it is intended to devise techniques and employ water models for deposition tests.

The tests described in this report have shown that the trajectory of a particle is greatly influenced by the particle characteristics. Consequently the patterns observed in a model by the use of illuminated balsa-wood dust can only be a crude approximation to the flow pattern. Great care should therefore be exercised in their interpretation.

References

1. R. D. Collins and M. P. Newby: *Nature*, 1948, vol. 162, pp. 224–225.
2. K. Rummel: *Arch. Eisenhüttenwesen*, 1936–7, vol. 10, pp. 505–510. 1937–8, vol. 11, pp. 67–80.
3. J. A. Leys and E. T. Leigh: *J. Iron Steel Inst.*, 1952, vol. 170, pp. 336–342.
4. C. N. Davies and Mary Aylward: *Proc. Phys. Soc.*, 1951, vol. 64, ser. B, pp. 889–911.
5. C. N. Davies and C. V. Peetz: *Proc. Roy. Soc.*, 1956, vol. 234, ser. A, pp. 269–295.
6. E. Brun and H. W. Mergler: *N.A.C.A.*, March 1953, T.N. 2904.
7. C. N. Davies: *Proc. Inst. Mech. Eng.*, 1952, vol. 1B, ser. B, No. 5, pp. 185–198.
8. H. Heywood: *Ibid.*, 1938, vol. 140, pp. 257–297.
9. A. E. Chamberlain: *A.E.R.E.*, 1955, HP/R 1261.

Historical Note No. 1 (Second Series)—

A Forgery in Iron

By H. R. Schubert

THE COLLECTION of ornamental cast-iron firebacks owned by the Sussex Archaeological Society and exhibited in Anne of Cleves's House at Lewes includes a fireback (shown below) which was for a long time the subject of special attention and considerable interest.

This fireback is remarkable for several reasons. The figure of a salamander, a lizard-like animal which was believed in antiquity to live in fire, is a very rare artistic motif used for the ornamentation of firebacks. Above this figure appears a date (1550), which is also unusual, since the majority of firebacks in England, as well as in other countries, bear no date. The importance of the date is increased by the fact that at the time of its first reproduction in literature it made the specimen on which it appeared the oldest fireback cast in England.* Another English fireback dated 1548 was not known at that time.†

The first to express doubts about the early date of 1550 was Professor W. R. Lethaby, who "thought that the second figure [i.e. the first "5"] was forged in both senses of the word."‡ An examination made recently by the present author proved that Lethaby's assumption was perfectly correct. There are even slight traces of a different numeral underneath, which had been carefully filed off and may have been a "6." That the original date was indeed 1650 and not 1550 is confirmed by a replica in the Museum at Rochester, Kent, which bears the date 1650.

The motive which prompted the forger is quite clear: by altering the date he produced the oldest specimen of its type known in England. The person of the forger, however, cannot be identified. Naturally, the disclosure that the Piltdown skull, discovered by Charles Dawson, and a number of items from his collection of antiquities were fakes has recently raised the suspicion that Dawson had a hand in forging the numeral on the fireback. Dawson, however, who died in 1916, should be ruled out; according to a catalogue, the fireback has been in the possession of the Sussex Archaeological Society since at least 1866, § almost half a century before Dawson drew attention to it.

*First described by J. Starkie Gardner in *Archaeologia*, 1899, vol. 56, Fig. 23, p. 158; subsequently by Charles Dawson in *Sussex Archaeological Collections*, 1903, vol. 46, p. 27; further in "Victoria County History of Sussex," vol. II, plate facing p. 242 (London, 1907).

†Reproduced by H. R. Schubert, *J. Iron Steel Inst.*, 1954, vol. 176, p. 36. The development of the art of casting firebacks in England is described by the author in "History of the British Iron and Steel Industry, c.450 B.C.–A.D. 1775," which is to be published shortly by Routledge and Kegan Paul Ltd., London.

‡W. R. Lethaby, *The Builder*, 1926, Oct. 1st, p. 538.

§ Evidence kindly supplied by the Curator of the Collections, Mr. N. E. S. Norris, F.S.A.

Correspondence on the Paper—

The Craze-Cracking of Metals*

By L. Northcott and H. G. Baron

Dr. **F. H. Scott** (Sheffield) wrote: The paper by Northcott and Baron provides a different method for investigating the influence of alloying elements on tendencies of steel to crack. Taking 500 cycles as an average figure for the experiments carried out by the authors, it is interesting to note that a maximum temperature of about 780° C might provide minimum thermal conditions for this type of cracking; this figure is higher than that which has been suggested in the past for crack formation arising from the hydrogen content of the steel, while it is lower than that which might be anticipated if crack formation of this form was a consequence of nitrogen in the steel, or nitrogen absorption consequent of the test.

This may well be a manifestation of the phenomena of cracking due to transformation stresses, and in this case the authors' macrophotographs are particularly interesting in that they could form a basis for discriminating very easily between these types of crack origin. The writer has observed (and used) the maze pattern produced on the surface of copper, which on cooling after hot rolling presents somewhat similar maze appearances with relevance to the flow lines of the material, a result of the rolling, and the authors too have taken note of this in some of their experiments.

So much discussion in the past has centred round the uncertainties of transformation stresses as a cause of cracking failure in steel that it would be most welcome to have a method of testing which provide some clear discrimination on the matter. The authors have gone some way towards helping us on this question.

Dr. **H. P. Tardif** and Mr. **W. Erickson** (Canadian Armament Research and Development Establishment, Quebec, Canada) wrote: The authors are to be congratulated for their paper, which is probably one of the most important attempts to date at rationalizing the phenomenon of craze-cracking. Although of great importance in industry, this phenomenon is also of considerable interest in armament work, where it is claimed by many to increase the wear of gun barrels. It is thought that the following observations are worth reporting.

A large number of crack-depth measurements have been made here on a particular type of barrel after firing various numbers of rounds. Figure *A* shows the shallowest and deepest cracks observed in a specimen, which vary from about 0·01 or 0·02 to 0·31 mm. Figures *B* and *C* show the crack-depth distribution curves for barrels fired 500 and 1000 rounds respectively. The approximate number of cracks measured was 600

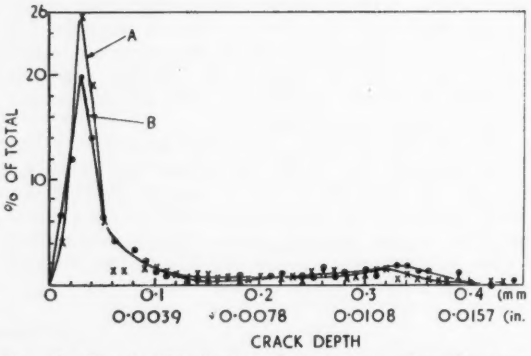


Fig. B—Crack distribution frequency curves for two barrels fired 520 and 510 rounds respectively

per barrel and the specimens representing approximately one-quarter of the circumference were taken from the most severely craze-cracked area of the barrel. It is felt, however, that these cracks are representative of other cracks around the whole circumference of the barrel and thus it would appear that the curves are bimodal in nature in that they have two maxima. With an increasing number of rounds from about 500 to 1000, it would appear that more cracks propagate to a depth between 0·2 and 0·4 mm.

If such crack-measurement studies were made in the authors' work it would be interesting to know if the same general distribution curve with two maxima was obtained, or if our curves are typical only of those generally observed in gun barrels. In a gun barrel, certain variables not studied in the authors' experimental test are unfortunately present, such as superimposed internal pressure, flow of gases at high velocity and high pressure on the surfaces, and possibly absorption of some constituents of the gases in the surface.

If a bimodal curve is observed only in gun tubes, perhaps one could assume that the second maximum in the curve is due to the superimposed internal pressure and that variation in internal pressure would affect the position of this maximum. On the other hand, could gas erosion during the first firings produce a roughening of the surface which would act as stress-raisers to produce a larger number of shallow cracks ?

Some interesting observations concerning the effects of stress concentration due to notches were made at the

Fig. A—Cracks of various depth and the heat-affected layer; 2% nital etch **× 120**

* *J. Iron Steel Inst.*, 1956, vol. 184, Dec., pp. 385–408.

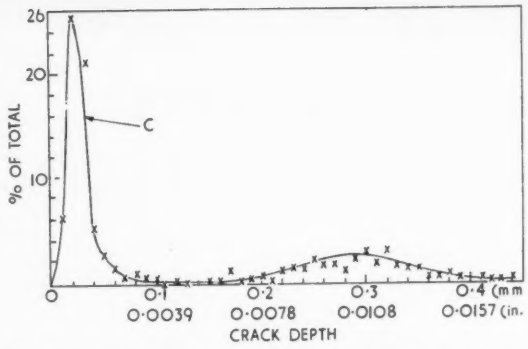


Fig. C—Crack distribution frequency curve for same type of barrel as in Fig. B, fired 1043 times

bore surface of a tube when this surface had been honed to a finish of 8 μin. Even scratches of this fineness will produce enough stress concentration to induce cracks along them (Fig. *D*) before the appearance of the usual craze-crack pattern. This photograph was taken at a position away from the most severely craze-cracked area of the tube, but it is assumed that the same effect would be present in the severely craze-cracked area after a few heating cycles.

The authors have mentioned that resistance to craze-cracking could in theory be increased by using material of higher yield stress. In the series of carbon steels used it appears that the craze-cracking is more severe the higher the carbon content, i.e. the higher the yield stress. This might be explained on the basis of decreasing ductility with increasing yield stress, but would not the higher hardenability of the higher-carbon steels also have an effect ? If hardenability has an effect, a cobalt steel may be expected to behave differently, as cobalt is perhaps the only element decreasing hardenability.

Finally, it may be interesting to report some observations made on a 2024–T–4 aluminium component from a small rocket. This part was under the flow of hot gases for a period of time of the order of milliseconds and was considerably eroded in this short time. Examination of the surface with a low-power microscope revealed a large number of cracks parallel to the grooves produced by erosion. A cross-section through the component also showed the cracks (*see* Fig. *E*). It would thus appear that this aluminum alloy, although having a low $E\alpha/K$ ratio, is prone to craze-cracking under severe conditions.

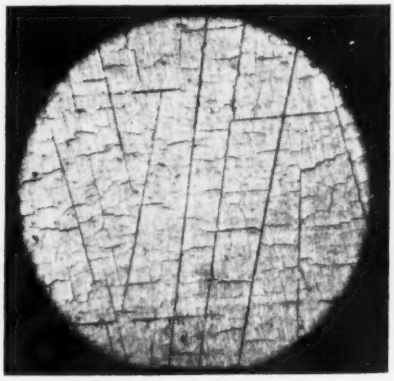


Fig. D—Long cracks initiated from fine honing marks × 8

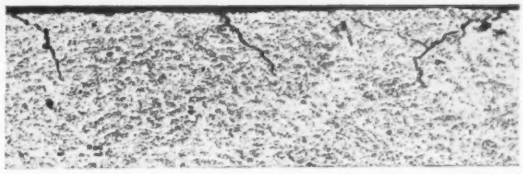


Fig. E—Cross-section of small aluminium projectile component showing cracks about 0·10 mm deep × 120

AUTHORS' REPLY

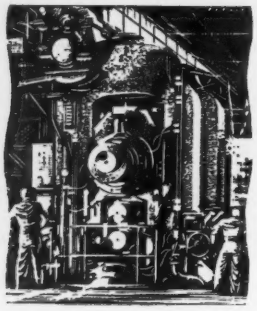
Dr. **L. Northcott** and Mr. **H. G. Baron** (Armament Research and Development Establishment) wrote: We wish to thank Dr. Scott for his contribution and fully agree with him on the importance of the strains set up during phase transformations and on influence of deformation in affecting the craze pattern.

We should like to thank Dr. Tardif and Mr. Erickson, who have put forward some interesting observations and suggestions. Dealing first with their observations on the bimodal distribution of crack depths in frequency curves, we have sometimes seen in gun barrels a fine network of shallow cracks within a coarse network of deep cracks, and this is another way of describing the same phenomenon. The same thing has also been observed on the surface of hot rolls, and we are inclined to believe that it is a widespread phenomenon not necessarily confined to components which are subjected to surface pressure.

A single crack relieves the tensile stress in the direction normal to the crack and one would expect the stress relief at the surface to extend for a distance of the same order as the depth of the crack. In this way one can explain the observed fact that the distance between similar cracks is often equal to about twice the depth of the cracks (this is not evident in Fig. *A* but can be seen in Fig. *E*). Thus the spacing of the initial network of cracks determines the maximum depth of most of these cracks and the position of the first peak of the frequency curve. The spacing of the network depends on the relative speeds of initiation and propagation of the thermal fatigue cracks. It is sometimes found that under severe conditions the cracks form quickly and propagate relatively slowly, giving a fine network. Under less severe conditions or with brittle materials, the cracks once started propagate relatively quickly, giving a coarse network.

The second and smaller peak in the frequency curve remains to be explained. In guns and other components where the thermal gradient is very steep there will be a certain crack depth beyond which the thermal stresses alone are too small to give appreciable rates of crack propagation, and the deeper cracks will then tend to approach this fixed value and produce the second build-up in the frequency curve.

We can confirm that cracks can be started from fine scratch marks in steel. We are interested to learn that craze-cracks have been produced in an aluminium alloy. This shows the danger of putting too much faith in a rule of thumb such as the $E\alpha/K$ expression. As to the rumpled type of cracking obtained when the temperature exceeds the Ac_3 point the hardenability of the surface layer may well be important, as Dr. Tardif and Mr. Erickson suggest. The surface layer is in effect quenched and hardened in every cycle and if the hardenability is inadequate the transformation of austenite will occur at a higher temperature and with a smaller volume change. We have found that additions of cobalt to a medium-carbon steel have little effect on the susceptibility to *this* type of cracking, whereas most other alloy elements increase it.



IRON AND STEELWORKS ENGINEERING

The Iron and Steel Engineers Group

Report of the 33rd Engineers Group Meeting

The THIRTY-THIRD MEETING of the IRON AND STEEL ENGINEERS GROUP of The Iron and Steel Institute was held at the Offices of the Institute, 4 Grosvenor Gardens, London, S.W.1, on Wednesday, 3rd April, 1957. Mr. W. M. LARKE, Chairman of the Group, occupied the Chair.

The whole day was devoted to the presentation and discussion of the paper on "Lubrication in Iron and Steelworks," by G. D. JORDAN (The United Steel Companies Ltd.) and H. JONES (Appleby-Frodingham Steel Co.), which was published in the March, 1957 issue of the *Journal* (vol. 185, pp. 389–408).

The paper was in two parts, Part I was presented by Mr. Jordan at the Morning Session, Part II was presented by Mr. Jones at the Afternoon Session.

LUBRICATION IN IRON AND STEELWORKS

Part I

Mr. **H. Harber** (The Steel Company of Wales Ltd.): The authors are to be congratulated on the large amount of valuable practical information gained from their wide experience of lubrication, which they have so ably presented. It has shown the importance of lubrication in iron and steelworks practice. However, in spite of an excellent presentation of the duties of a lubrication engineer in a general sense, I feel that a clear definition of the status and duties of the specialized lubrication personnel, in iron and steelworks in particular, is essential. Lubrication at Abbey Works over the past six years has developed as follows.

With increasing production, planned maintenance has obviously assumed greater importance and lubrication has had to be recognized as part of the mechanical picture, with the result that the work of the specialist lubrication staff, in the case of day-to-day maintenance, has merged into the main mechanical organization, and the lubrication staffs for such work operate under the responsible mechanical engineers.

All such lubrication staffs are assisted when necessary by a headquarters lubrication staff who are practically free from day-to-day-maintenance, and who can therefore concentrate on overall problems such as lubricant supplies, qualities, reduction of grades, standardization of lubrication equipment, improvement in lubrication methods, etc.

In my opinion this organizational set-up ensures that a much more effective planned maintenance programme can be carried out than is possible in the case of control of lubrication staff by other than mechanical maintenance departments.

The head of the headquarters lubrication staff, who also coordinates the whole lubrication organization, is the works lubrication engineer. He is responsible to the chief maintenance engineer to whom he acts as lubrication advisor.

The colour coding of lubricant drums, other containers, and machinery, has to overcome several obstacles. In most works already a colour coding for water, steam (high, medium, and low pressure), compressed air, water mains, gas mains, etc., is used, the supply of colours is already strained, and both time and plant conditions tend to make colour differentiation difficult. The marking of drums before issue can no doubt be carried out with the aid of stencils, but often considerable handling of the drums is necessary during the operation.

I would like to emphasize the importance of planning lubrication maintenance inspection which should form an important part of the mechanical planned maintenance. For this, an up-to-date lubrication schedule covering the entire plant is essential, and at Margam we have found that the most convenient form for this is a card-indexing system, the cards being made to our own design with loose sheets that fit over the main card, one of which can be of squared paper for graphing; the card size is 5 in. × 8 in. The cards fit on easily removable wires on the usual filing tray, and the entire set-up is very compact.

Large numbers of individual items can be scheduled in an extremely small space and movable indicator date-tabs are attached to the main card to set the date when next inspection is due. One of the main advantages is that a movement of plant, or modification, or change of lubricant can be carried out without affecting the rest of the lubricant schedule.

Another valuable lubrication aid is the use of permanized Perspex sheets with maintenance instructions on one side and lubricant schedules on the reverse. These are most useful, particularly on all types of mobile plant.

My final point is that great stress is placed on the training of personnel in lubrication in an endeavour to make them 'lubrication minded' so that machine operators and maintenance people are aware of lubrication and how it can affect the plant or machines they handle or maintain, and care is taken in selecting key lubrication-department personnel to ensure that they are capable of expressing themselves well, and that they can lecture to works groups when necessary.

Close liaison is maintained between the works library and the lubrication department to ensure an up-to-date list of all appropriate literature, which is circulated by the headquarters section to the departmental lubrication staffs.

Mr. **Jordan:** Mr. Harber's spproach to industrial lubrication engineering is very commendable and although the purpose of our paper was not to define the status and duties of the industrial lubrication engineer, we are naturally anxious, if only by implication, to give some indication of his responsibilities and of the justification for his position in the iron and steel industry.

Mr. Harber has quite rightly emphasized the importance of methods of controlling a lubrication programme by maintaining proper records and supported by adequate training methods. We are firmly of the opinion that some form of lubricant classification (in principle similar to that described in our paper) is an essential basis to any system of control. In connection with training methods, we would strongly recommend the use of simple transparent models* as an aid in demonstrating some of the principles of hydrodynamic lubrication.

We agree with Mr. Harber's references to the difficulties of colour code systems particularly under the extreme conditions prevailing in iron and steelworks. We do not, however, feel that these difficulties should condemn colour code systems, even under such conditions, without further investigation. The system used at Mannesmann Hüttenwerke is employed as far as the containers on centralized lubricating systems and is probably so successful because no attempt is made to identify individual lubricating points. The sequence of operations in using the colour code is perhaps best illustrated by reference to Fig. *A*.

Mr. **H. J. Knight** (Shell-Mex and B.P., Ltd.): I did not come prepared to raise any highly technical questions, but I am glad to offer my congratulations to the authors of this paper.

When it was first mooted that industry, especially the iron and steel industry, had need of lubrication engineers, many people thought them unnecessary, and some regarded the first lubrication engineers, especially those from the oil companies, as at best a necessary nuisance. In time, however, the profession of lubrication engineer has become fully justified.

The authors must be congratulated in particular on their simplification of what has always been regarded as a very involved and somewhat mysterious subject, mystery apparently being attributed to the suppliers and manufacturers of lubricants. However, the oil industry as a whole has no desire to make a mystery of its products. It manufactures them to assist in all forms of industry, and employs a vast number of people to keep it up to date.

Iron and steel is a basic industry in the U.K., and I think it would be right to say that the oil industry also is almost a basic industry in that it employs a vast number of people, supplies a service, and contributes a great deal technically to industry in one form and another. The complication arises when it comes to the question of the usage of these petroleum products such as lubricating oil and grease.

In a large integrated steelworks there is an example of almost every form of mechanical engineering and electrical engineering, plus many other things which are rather abstruse and which we generally call 'process engineering.' The authors have not touched very much on the process side because one could discuss it for a week and not get a complete answer to all the problems and questions which arise today not only in the petroleum industry but also in the steel industry.

Coming to the term 'lubrication engineer,' we hear of many types of engineer; mechanical, electrical, electronic, chemical, etc., but the lubrication engineer has a very big job because he is forced to become familiar with all these forms of engineering. If he is to do his job properly he has to know the intricacies of the operation of the pieces of plant concerned. In a steelworks is every form of gear and bearing that man has ever invented, besides something indigenous to a steelworks, the rolling mill. This is a peculiar piece of engineering not always very predictable, and the lubrication engineer is often asked to produce a miracle out of a barrel to make this piece of equipment work, something which should have been done long ago by the designers in collaboration with the lubrication engineer and the lubricant supplier.

Collaboration between the plant builder, the lubrication engineer, and the lubricant supplier is very important. In the last ten years plant builders have become well aware of the value of this collaboration, and some of them now employ their own lubrication engineers. This has been of great value to the petroleum industry, and, I am sure, to the iron and steel industry through the lubrication engineer.

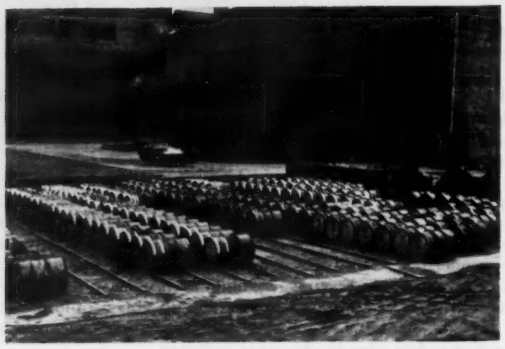
Plant builders are far better than they were 10 or 15 years ago, when they simply designed plant to do a job and expected some mysterious form of lubrication to make it work. Nowadays they are more amenable to discussion with the user and supplier of the lubricant than before, and in the petroleum industry we endeavour to rationalize as far as possible the lubricants recommended for similar plant. However, there is always the plant builder who has peculiar views and who wants to be a little different from the orthodox.

The equipment manufacturers who make oil systems, grease systems, etc., have made great progress in the last ten years and have been of great help to the petroleum industry. Lubrication engineers will probably support the view that the equipment manufacturers, though a little slow to start, have greatly assisted both the users and suppliers of lubricants.

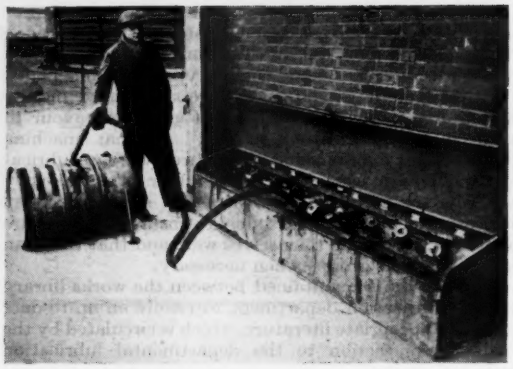
I should like to ask the authors whether or not the plant or processes in the steel industry are beginning to demand what are called 'synthetic lubricants,' lubricants with a very elevated flashpoint or virtually no flashpoint, and a melting point far beyond that which can be achieved with an ordinary petroleum product.

The Chairman mentioned, in opening the meeting, that many years ago suet was used as a lubricant. That reminded me vividly of one of the first jobs which I had as a so-called lubrication engineer. I was sent to a large steelworks and told that I had somehow or other to make an ordinary lubricant take the place of suet, as suet was expensive and the smell was terrible. I struggled for many weeks but nothing seemed to work. Finally the chief roller said to me, "Look, young man, you haven't a

* J. Boyd: *J. Amer. Soc. Mech. Eng.*, 1948, vol. 70, pp. 589–592.



(i) Containers marked with appropriate colour code after acceptance testing, awaiting use

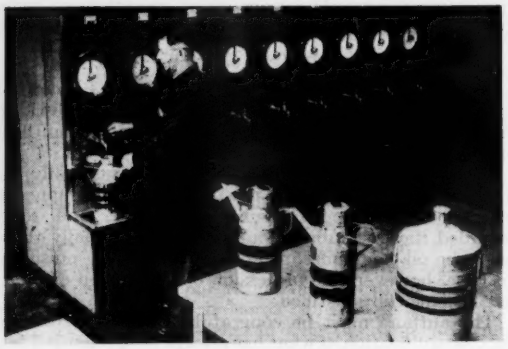


(ii) Lubricant transferred by vacuum pump from barrel to storage tank via appropriate connection (also carrying colour code)

Fig. A—Sequence of operations in using colour code system at Mannesmann Hüttenwerke

(iii) Storage tanks in oil store marked with appropriate colour code and fitted with discharge pumps

(v) Centralized lubricating system containers marked with appropriate colour code



(iv) ' Milk bar ' service to supply lubricant into containers marked with appropriate colour code

hope, and I'll tell you why. Every Monday morning the local purveyor of suet delivers here about 30 stone of butcher's suet. When it arrives it's nice and fresh and the men often find kidneys in it. At the end of the week, when it's not so fresh, they manage to breed maggots to go fishing with on Sunday. Until you can provide a lubricant which has kidneys on Monday and maggots on Friday, I'm afraid you won't succeed! "

When war broke out we could not afford to use suet for the lubrication of rolling mills. My work was resuscitated, and it was found that the lubricant which we had devised was quite good. The equipment manufacturers produced equipment which made this lubricant work.

Dr. **F. Eisenstecken** (Gelsenkirchener Bergwerks-A-G): I fully agree with the authors' conclusion to Part I of their paper. With particular reference to the colour-code system (Fig. 3 of the author's paper) used by the Mannesmann Hüttenwerke, there have been further improvements in the application of colour coding by the German Standards Institution, the Lubrication Section of the German Mining Institute, and the German Iron and Steel Institute (V.D.E.). Figure *B* shows the basis of this development. It uses different colours and shapes for different oils and greases. These symbols are used on tanks, cans, grease-guns, etc. Also, lubrication points on the machines have small labels bearing similar signs.

By fundamental study it was possible to specify for use in German mines nine oils and three greases. The results of this work have been published in a booklet* which is available to anyone interested.

The V.D.E. is trying to develop a similar system beginning with an investigation of all kinds of oils and which will lead to the standardization of an oil or grease for every lubrication purpose. The susceptibility to oxidation depends on the structure of the particular oil and on the operating conditions in the machine. Generally it has been found that oils containing naphthenes resist higher temperatures better than paraffin-containing oils. At the same time it was observed that at temperatures over 300° C, napthenic oils leave a graphite-like residue which does not lead to any lubrication difficulties, while paraffin oils give a coke-like residue which interferes with lubrication.

We also believe that the viscosity index is a guide to the properties of certain oils, e.g. steam-cylinder oils. German oil companies, however, do not accept this finding, but it is hoped that the viscosity/temperature relationships will eventually be accepted as a common basis.

* " Richtlinien für die Schmierung von Bergwerksmaschinen," Glückauf-Betriebsbücher, Band 5, Verlag Glückauf, G.m.b.H., Essen, Huyssenallee 105.

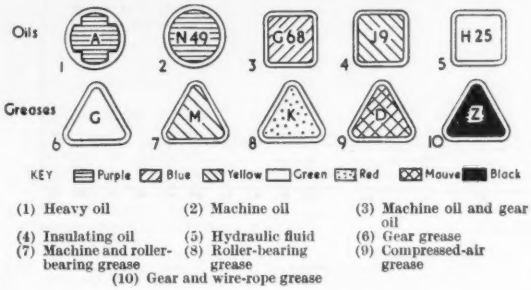
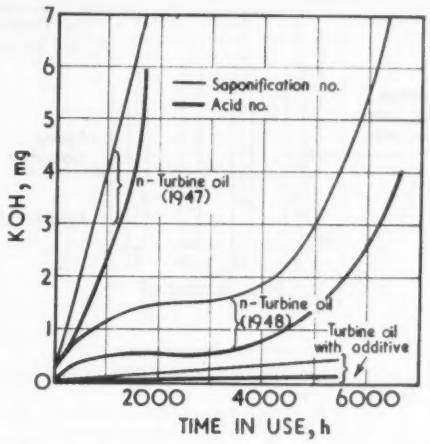


Fig. B—Lubricants for use underground



Turbo-compressor
Built 1926; Capacity 25000 m³/h; Compression ratio 1 : 6; Steam inlet temp. 300° C; Steam press 10 atm; Quantity of oil 700 kg; Speed 3880 rev/min

Fig. C—Duration of service of different oils in turbo-compressor

One of the most difficult problems encountered by German investigators is the reaction between some oils and water, and the fact that the test conditions have to be adjusted to practical conditions. For example, rolling-mill oils come into contact with water at temperatures not above 50° C, while turbine oils come into contact with steam when the stuffing boxes are not completely tight. Therefore it is clear that the tests for such oils must be of an entirely different type.

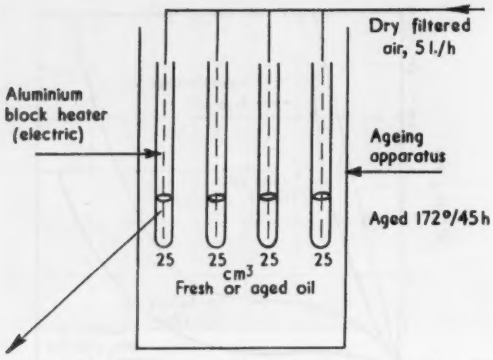
I refer now to some oil specifications that we have developed.

Turbine oils—It is known that the tendency of a turbine oil to deteriorate is fixed by determining the acidity and saponification value for that oil. Figure *C* shows the change in a turbine oil, with reference to the acidity and saponification value, in relation to the number of hours in use. Oils supplied in 1947, for instance, reached such high acidity and saponification value in a turbo-compressor after 2000 h that they had to be replaced. In 1948 the oils had already shown some improvement, and it was seen that oils with additives behaved best in the turbo-compressor. On re-examination, other turbine oils showed that their evaluation by acidity and saponification value numbers was no longer well defined. This led to the development of a new test.*

This was carried out by centrifugation, then tested in the apparatus shown in Fig. *D* with dry air for 45 h at 172° C. The oil was then analysed for acidity, saponification value, resins, and asphalt. A factor *F* was then calculated which, on the basis of the practical findings from examination of deposits, can have various values. As shown in Fig. *D*, a factor of $F \leq 55$ is satisfactory, while a factor of $F = 55$–70 gives no particular trouble. The oil is of borderline quality when $F = 100$.

Figure *E*(*i*) shows the course of the deterioration. It was shown that turbine oil in a turbo-generator should be changed when $F = 75$ (after 9000 h use). In the circumstances, however, this was not possible, and the oil was used for another 3000 h when the machine was then stripped. On opening the bearings a thick deposit of tar and resin was found. This was also found in the dead

* *see* " Erdöl und Kohle," 1950, vol. 8, pp. 75–81.



(1) 5 cm³ + 100 cm³ *n*-hexane (flask capacity 300 cm³)
(2) + kryolith, synthetic, finely powdered, dried at 105° C (in small amounts and shaken)
(3) Filtered
(4) Residue treated with chloroform
(5) Solution evaporated
(6) Dried to constant weight (at 50° C) = petroleum resin (E_H)
(7) Experiments with 3 residual aged samples repeated (average of 4 experiments)
Hard asphalt precipitated with *n*-liquors
Deterioration factor (F)

$$\left[Fn - (H_A) + \frac{3(E_H)}{5} + \frac{3(N_Z + V_Z)}{25}\right]$$

or

$$F - (N_Z + V_Z) + (E_H)^2 + (H_A)^2$$

where N_Z = acid no., V_Z = saponification no., E_H = petroleum resin, H_A = hard asphalt

F ≦ 35 (group I)	Good
F ≦ 55 (group II)	Suitable when close to above value. Beware of sediment separation.
F > 55–70 (group III)	If used, even less suitable. Increasing separation of sediment.
F > 100 (group IV)	Not useable. Excessive sedimentation and beginning of asphalt formation.

Fig. D—Scheme of analysis for examination of petroleum resins, deterioration factors, and group ratings

Table A

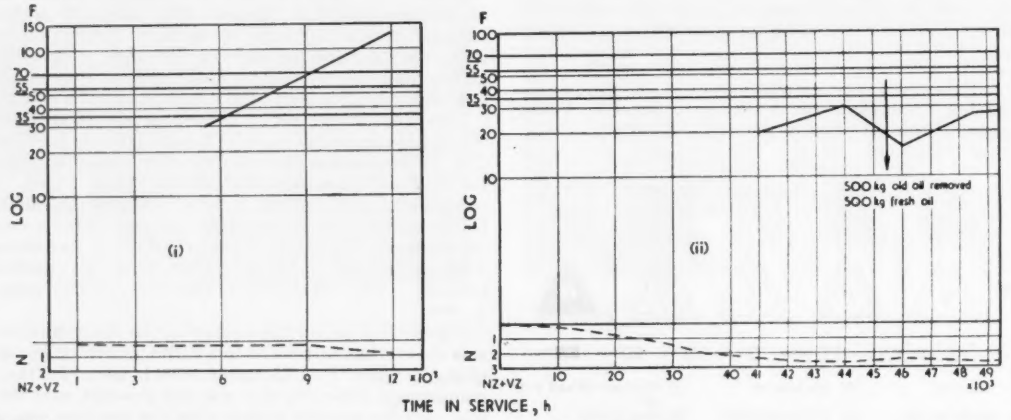
STEAM RESISTANCE OF TURBINE OILS ACCORDING TO *DIN* COMPARED WITH TIME IN USE

Oil	Tested according to DIN 51-591 — Experiments in 5 different labs.					Conclusions	Behaviour in machine for 500–1000 h
1	+	−	−	−	−	−	−
2*	+	+	−	−	−	−	+
3	+	−	−	−	−	−	+
4	+	+	−	−	−	−	−
5	+	+	+	−	−	+	not used
6*	+	−	−	−	+	−	+ turbid
7	+	−	+	−	−	−	−
8	+	+	+	+	+	+	not used
9	−	−	−	+	+	−	+

* Oil with additive (against oxidation and corrosion)
\+ Emulsion formed
— Rapid separation of water from oil

spaces of the bearing cover and oil pipes. Under working conditions, if it is not practical to change the oil with a high deterioration factor it may be possible to run off some of the oil and to top-up with an equal amount of fresh oil. As is shown in Fig. *E*(*ii*) this practice is a mistake, for shortly after topping-up, the deterioration factor increased again, in effect poisoning the fresh oil. Where replacement is necessary we consider it essential to clean out completely the lubrication system and refill with fresh oil. In Fig. *F* a series of curves for the oil factor for turbine oils in circulating systems are shown in relation to time. It has been established that the turbine oils give very definite results. The critical point is that this oil reacts sensitively with water to form a more or less stable emulsion.

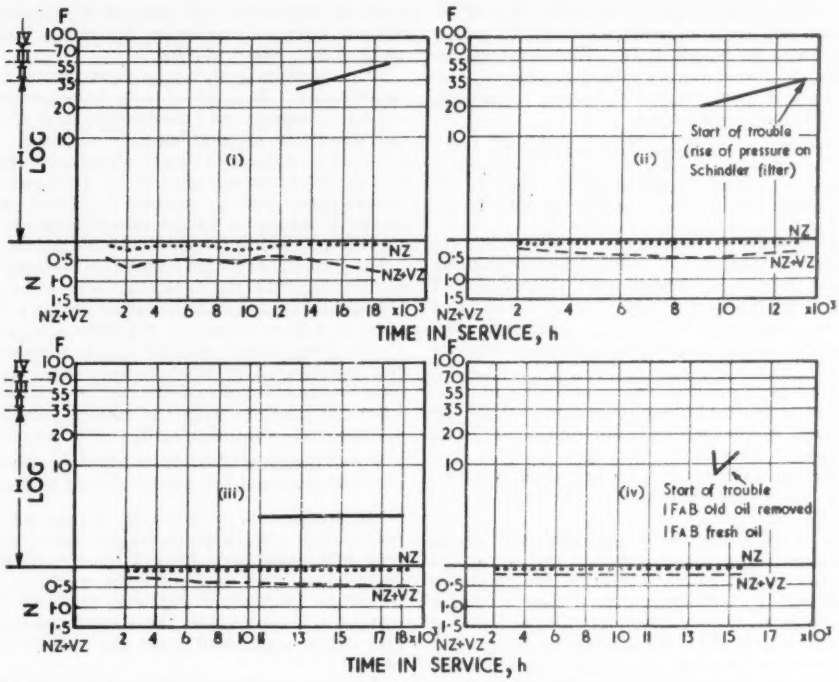
Table *A* shows results of a standard German steam test for testing resistance to emulsification. Nine different oils were tested in five laboratories using the same method. The first oil emulsified in the first laboratory but all the others produced negative results. The negative result was accepted, and in practice the oil does not emulsify. With the second oil two laboratories found that it did emulsify, three reported that it did not. It was concluded that this oil did not emulsify, but in practice it did.



(i) *Turbine*
Built 1927; Capacity 1650 kWh; Speed 3000 rev/min; Steam inlet temp. 300° C; Steam press. 11 atm; Filled with oil Aug. 1952; Quantity of oil 1000 kg; Times topped up, 10

(ii) *Turbo-compressor*
Built 1948; Capacity 55000 m³/h; Speed 3850 rev/min; Steam temp. 335° C; Steam press. 13 atm; Filled with oil May 1948; Quantity of oil 2500 kg; Times topped up, 10

Fig. E—Deterioration factor of uncompounded turbine oils at present in use



(i) *Turbo-ventilator*
Built 1948; Filled with oil, Jan 1942; Quantity of oil, 520 kg

(ii) *Turbo-compressor*
Built 1931; Capacity 55000 m³/h; Speed 3300 rev/min; Steam inlet temp., 300° C; Steam press. 12·5 atm; Filled with oil Oct 1951; Quantity of oil 2000 kg; Times topped-up, 8

(iii) *Turbo-compressor*
Built 1924; Capacity 32000 m³/h; Speed 3750 rev/min; Steam temp. 340° C; Steam press. 11 atm; Filled with oil Sept 1951; Quantity of oil 2200 kg; Times topped-up, 6

(iv) *Turbo-generator*
Built 1918; Capacity 6000 kWh; Speed 3075 rev/min; Steam inlet temp. 300° C; Steam press. 15 atm; Filled with oil Sept 1951; Quantity of oil 800 kg; Times topped-up, 12

Fig. F—Deterioration factors of compounded turbine oils at present in use

Similarly conflicting results were obtained with all the other oils. This led to a new method of testing* which has given consistent results.

Rolling-mill and gear oils—Table *B* lists the properties of normal oils in gears and rolling mills. We believe that the oil should be of low density for the better separation of water. The viscosity is best specified by the makers. We are now investigating the ageing of the oil, and for this the test mentioned above is used, as well as a so-called 'carbon-residue test' to determine carbonization residue. When the results lie within the limits already found it is to be expected that, in spite of different viscosities, there will be no trouble due to deterioration. The values given in Table *B* apply to a normal oil. For compounded oils and those containing organometallic compounds these specifications are not of much value, just as in the case of acidity determination and saponification values which, though necessary in determining the deterioration factor, may themselves give large deviations in various laboratories. If an oil is chosen

* *see* "Brennstoff-Chemie," 1956, vol. 37, pp. 336 ff.

Table B

PHYSICO-CHEMICAL DATA ON UNCOMPOUNDED ROLLING-MILL OILS

(Average of 10–15 samples)

Viscosity 50E Viscosity 50cP Viscosity 50cS	≲ 9–10 ≲ 61–69 ≲ 68–76	≲ 11–13 ≲ 75–89 ≲ 83·5–99	≲ 15 ≲ 103 ≲ 114	≲ 22 ≲ 151 ≲ 167	≲ 31–33 ≲ 213–227 ≲ 235–251	≳ 38 ≳ 262 ≳ 290
Density at 20° C max.	0·900	0·900	0·900	0·905	0·905	0·905
Flashpoint, ° C min.	245	255	265	285	300	305
Pourpoint, ° C min.	− 20	− 20	− 15	− 15	− 15	− 15
V_J max.	85	85	85	90	90	90
Ash, max. %	0·0	0·0	0·0	0·0	0·0	0·01
Asphalt, max. %	0·01	0·01	0·01	0·02	0·02	0·05
Carbonization residue, max. %	0·20	0·25	0·25	0·65	0·75	1·0
C′–C, max. %	0·3	0·4	0·6	1·0	1·01	1·5
F′–F, max. %	2·5	3·0	4·5	5·0	6·0	7·5

C′ = Carbonization residue after ageing
F′ = Factor after ageing

which is not compounded with a viscosity of 9·0° E (68·5 cS) this oil will have an acid value of 0·04 and a saponification value of about 0·10. When increasing amounts of lead naphthenate are added to this oil, the saponification value rises to the following values as given by two different laboratories.

	Lead naphthenate, %				
	0	5	10	15	20
First laboratory	0·04	3·92	6·09	9·94	11·90
Second laboratory	0·10	1·6	6·9	20·39	40·6

Similar observations were also made when the oil contained higher proportions of sulphur compounds as extreme pressure additives. Therefore it was concluded that the deterioration test for oils with additives is of little value; the tendency of the oil to oxidize is considerably changed as compared with that of turbine oils.

Unfortunately, compounded rolling-mill oils in contact with water form stable emulsions but part of the compound, especially that with a lead-naphthenate base, may be separated through centrifugal action. The stability of the emulsion is further increased by small rust particles which are formed by corrosion of the bearings and containers.

Compressor oils—These present a special problem as they tend to crack under the influence of high pressures and temperatures. German investigators are therefore trying to find testing methods to give a clear value for the resistance of an oil under different conditions found in the compressor, where the pressure/temperature value etc., in conjunction with the deterioration factor could be given a limit. Details of these investigations will be published later.

Mr. **H. Stafford** (United Steel Companies Ltd.): As secretary of the committee of lubrication engineers of which Mr. Jordan is chairman I must make a point that he did not mention; that as a result of this work there have been substantial financial benefits.

My particular subject is that of standards. The authors refer briefly to B.S. 210. This standard was referred to when this work was first started, but it gave no help whatever. The classification and coding, and general arrangements described in the paper were developed in various steps. There is one step further to which Mr. Jordan did not refer, but which ought to be mentioned from the point of view of standards. The coding system contains three groups of figures. The first identifies the lubricant (oil, grease, or intermediate product); the second classifies the group (e.g. gear oil); and the third is the viscosity classification or N.L.G.I. number. Where oils require to be compounded or to possess extreme pressure additives, or, in the case of motor oils, have to be further identified, we have added a letter symbol as a suffix, but a more precise definition of these symbols is required so that they may be used more freely. They should not be restricted but should be suitable for any group classification.

Where oils are compounded and embody animal or vegetable-type fatty additives, natural or synthetic, we have the symbol *C*. For extreme pressure oils, the letters *EP* have been used freely, but there is ambiguity since it is necessary to distinguish between active and non-active types, so that we have adopted the symbols *EP* for non-active and *AP* for active. For transmission oil we have *ET* and *AT* for non-active and active. For motor oils the expressions 'regular,' 'premium,' and 'heavy duty' have changed in meaning in the last few years, and further definition was necessary, the symbols adopted being *R* for regular, *P* for premium, and heavy duty split into three classes, *HD*1, *HD*2, and *HD*3, in increasing order of detergency. There are no existing symbols for soluble oils, and as it is necessary to distinguish between machining, hydraulic, and rolling oils, we used *SM*, *SH*, and *SR*.

Identification is the only shortcoming of the grease classification. It is possible to have greases which are similar in respect of classification and N.L.G.I. rating but dissimilar in soap-base. We agreed, therefore, to incorporate a simple suffix to identify the soap-base, and to use the chemical symbol for this purpose, as it is unambiguous and is capable of infinite variation. We agreed to adopt Ca for calcium or lime, Na for soda, Li for lithium, Na/Ca for soda-calcium, and so on.

I should like to suggest that this meeting might send a resolution to the B.S.I. asking for a revision of B.S.210. It is quite likely that in the future people will be adopting entirely different symbols for these additive properties. Further, we should ask the B.S.I. whether or not this can be taken up internationally, so that we can have an international standard to define these additives. Otherwise, the position from the supply point of view may become quite confusing in the next five or ten years.

The **Chairman** (Mr. W. M. Larke): To get an international standard will take at least five years.

Mr. **Jordan**: We did not discuss the role of petroleum products in process engineering as many aspects of process lubricants are clouded by controversy, personal preferences, and trial-and-error methods. Also, many industrial lubrication engineers have no part in their control and application. This applies particularly to roll oils which could well form the subject of a separate paper.

In answer to Mr. Knight's question about the demand for synthetic lubricants in the steel industry, we can only speak from personal experience. In the U.K. we have not found that at present there is a great demand for synthetic lubricants. There has been limited use of the silicones, but generally their high cost prohibits extensive application. In the U.S. the non-inflammable hydraulic oils have been used extensively in iron and steelworks, but this may be due to the more extensive use of hydraulic methods of control on furnaces and hot-rolling-mill equipment where a breakaway of oil could lead to serious fire hazards, or it could be simply a passing phase. The demand (if it exists) for synthetic lubricants could largely be controlled by design which takes into account all the possible operating features.

We should like to thank Dr. Eisenstecken for his remarks. His interesting additions to what we have said about colour coding should encourage further study. We assume that the labels to which he refers are plastic and permanent, which obviates re-painting problems, and that the different shapes will not only serve to identify the lubricant but will, to some extent, reduce the difficulties of colour-blind operatives.

His contribution on testing methods and the results of several investigations in Germany are very interesting. We would agree with his experiences with turbine oils. The additive-type quality has extended the life of turbine oils extensively and so far as we are aware, all turbines commissioned in the U.K. to-day are filled with life-guaranteed oils. The problems associated with the demulsibility of oils are well appreciated in the U.K. iron and steel industry. The steam emulsion number is not recognized as a satisfactory measure of demulsibility in circulating systems. We are more interested in test methods which involve mixing oil with water and measuring the rapidity and degree of separation. The difficulty with these arbitrary test methods is that an assessment made on a new oil is not necessarily borne out in practice, owing to the sensitivity of demulsification to contaminants.

We agree with all that Mr. Stafford has said about B.S. 210. It was because of the limitations of this standard that we adopted the A.S.T.M. approach and modified their viscosity classification (still only in its proposed form) to suit our requirements. The extension of our code letters, which he mentioned, is the result of work done since this paper was published. We are hesitant about the extent to which we shall use these as we are anxious that our definitions should receive general approval. The symbols we have suggested for further identification of iron and steelworks' lubricants are shown in Table *C*. Their use is illustrated in Table III of the paper. The Ministry of Supply, in their specifications, are also aware of this problem of identifying lubricants and use a somewhat similar system.*

Dr. **F. W. Griese** (Verein Deutscher Eisenhüttenleute): In their introduction, the authors say that' the fundamental function is to lubricate.' However, in considering the present state of development of the industry I think that this can be better stated as the ' reduction of wear and frictional losses.' That takes into account all the aspects involved in lubrication and the manufacture of lubricants as well as the manufacture of bearings and gears.

In German steelworks we are trying to reduce the number and types of lubricants in use. This cannot be done with the ordinary specifications, because in these only the lowest acceptable values of various parameters are given. Thus several lubricants which may meet the requirements of an ordinary specification are not identical and therefore cannot meet more specific requirements. Therefore we try to establish a standard for various kinds of lubricant such that the supplies from different manufacturers will be so very similar that they will all fulfil the same requirement in the steelworks. Only by such standardization will it be possible to reduce the variety of lubricants used.

When today we speak of ' gear oil ' and ' turbine oil ' etc., we must not forget that in the steel industry 50 years ago they spoke of ' crankcase iron,' ' gearbox cast iron,' ' bridge steel,' etc. Today we do not use these terms but standardize according to the properties of the particular steel. This is also necessary in the case of lubricants, and similarly we could reduce the number of grades of lubricants. When we speak of lubrication practice we not only name the lubricant but must also specify the construction of the part to be oiled.

In many modern rolling mills there are still sleeve bearings with oil grooves, for example, from which one must conclude that many designers do not know what was said on this subject 80 years ago. From the engineering point of view it is wrong to correct for non-observance of sound design principles by the use of special lubricant

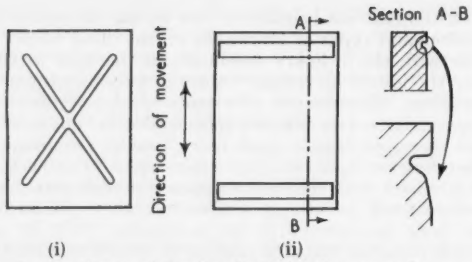
* *see* " Handbook of Service Lubricants and Temporary Protectives," 1954, 4th edn., Ministry of Supply D.M.X.R.D. (M.X.6.), Shell-Mex House, Strand, London, W.C.2.

Table C

SUGGESTED SYMBOLS AND DEFINITIONS FOR FURTHER INDENTIFICATION OF INDUSTRIAL LUBRICANTS

(A) Lubricating Oils

Classification	Code Symbol	Definition
Compounded	C	Applied to oils embodying animal and vegetable-type fatty additives which may be natural or synthetic
Extreme pressure	E.P.	Applied to oils containing ' non-active '-type extreme pressure additives
	A.P.	Applied to oils containing ' active '-type extreme pressure additives
Transmission	E.T.	Applied to oils used in automotive-type transmission units and containing ' non-active ' additives
	A.T.	Applied to oils used in automotive-type transmission units and containing ' active ' additives
Motor crankcase oils: (i) Regular	R	Applied to motor crankcase oils where operating conditions are not severe and the oils contain neither added detergents nor particular oxidation stability. These oils may, however, be naturally mildly detergent
(ii) Premium	P	Applied to motor crankcase oils, containing ' mild ' added detergency and good oxidation stability to suit them for more severe operating conditions
(iii) Heavy duty	H.D. 1 Supplement 1	Applied to motor crankcase oils containing high added detergency and suitable for severe operating conditions
	H.D. 2 Supplement 2	
	H.D. 3 Supplement 3	
Soluble oils: Machining	S.M.	Applied to soluble-type oils used for machining purposes
Hydraulic	S.H.	Applied to soluble-type oils used for water hydraulic systems
Rolling	S.R.	Applied to soluble-type oils used for rolling solutions
(B) Lubricating greases (classification by soap base)		
Calcium (lime)	Ca	It is only necessary to indentify a lubricating grease further by its soap base. The appropriate chemical symbol is used for this purpose
Soda	Na	
Soda-lime	Na/Ca	
Lithium	Li	
Lead	Pb	
Lead-lime	Pb/Ca	



(i) Crossing oil grooves in bearing with short sliding movement
(ii) Bearing surfaces with oil grooves to maintain efficient lubricating film

Fig. G—Obsolete and modern designs for bearings used in steelworks

and additives. This leads not only to faulty types of construction, but also to a great multiplication of different kinds of lubricants.

The evolution of the ' Morgoil ' bearing, for example, has shown that plain bearings can be designed for use in rolling mills working by the system of flood lubrication, so that the oil film carries the load. On the other hand, it is also found that there are always smooth parts with only a short sliding movement and which have crossing grooves as shown in Fig. *G*(*i*). With this arrangement no lubricant film with any bearing capacity can be formed. Why is no advantage taken of this knowledge to use, for example, the Morgoil bearing and to make the bearing surfaces with oil grooves as in Fig. *G*(*ii*)? We should certainly have less difficulty in steelworks with bearings and lubricants if these fundamentals were generally applied.

Mr. **F. Wunsch** (Mannesmann A-G, Germany): The authors have chosen 18 classes of oil. If we plot these horizontally against the viscosity vertically, we get straight lines showing a kink at No. 9 (Fig. *H*(*i*)).

In some German standards the viscosity is so arranged, that we do not get straight lines but curves, for instance in DIN 51 510 ' Normal oils ' and in DIN 51 506 ' Compressor oils.' There are several reasons for systematizing the viscosity according to preferred numbers. A proposal made by Dr. Göttner of Hannover, one of the German oil research workers, gives numbers which repeat themselves (Fig. *H*(*ii*)).

Dr. Göttner and other German researchers do not want to use centistokes and they do not like the idea of centistokes being the international unit. They want the unit to be the centipoise, because this is the only real viscosity. We also find it in several formulas, for instance in that developed by Professor Vogelpohl (Göttingen), for the calculation of plain bearings : $P = C : \eta n_a V$, and so we prefer centipoises to centistokes. At present there is a slight difference of opinion between us and our friends in the oil companies about this, but I hope that in time the oil companies will agree to use centipoises instead of centistokes for classification.

Monsieur **H. Desecures** (Chambre Syndicale de la Sidérurgie Française), speaking also on behalf of Monsieur **J. Hennevin** (USINOR, Denain): We are pleased to have been invited to this meeting to discuss this paper.

French steelworks have also appreciated the importance of lubrication and there is now in many plants a lubrication engineer responsible for this department. French steelworks have contacts with English manufacturers, and it is desirable that they should adopt the same position as English steelworks towards these manufacturers, and the same basis in regard both to techniques and to the terms used.

The studies of our committee began more than a year ago. We started by establishing a single classification for all steelworks. These studies are not yet finished. Among the various French specifications we have found that those adopted by the French coal industry seem to be the most convenient for us, because its requirements, consumption, and methods of supply are very similar to steelworks practice. The coal industry specifications have behind them ten years of successful experience. Our committee is working with a committee of the coal industry to establish specifications which will be similar for both industries.

The bases of the classification suggested in the present paper are not, we find, quite the same as those which we have adopted so far as oils are concerned. Our classifications are:

(1) Oils are classified according to their characteristics and not according to their uses.

(2) Two main classes have been established: ordinary oils, and special oils. The first can be specified by their own characteristics; they can even be mixed by the users. The special oils are those which have not only their own characteristics but also a specific origin, such as the naphthenic oils, or incorporated additives. These qualities imply the full responsibility of the supplier, and their brand names generally have to be maintained.

(3) Except for thermic engines, the machines generally work at constant temperature, and therefore we think that it is not necessary to specify a viscosity index to define the viscosity, which is the most important characteristic.

(4) The groups of oils are defined by the viscosities at the temperature of use. These viscosities are rated in centistokes, this being the unit internationally accepted and which is used in laboratories and supply departments. Generally in France, however, users know the viscosity Engler; it is the old classification accepted in France of the classes A, B, C, D, etc., with a number giving the viscosity Engler, which we have taken for the classification so that it will be better understood and adopted by users.

(5) We have not yet undertaken the study of a colour-code system, but it might be dangerous to use colours as proposed by the example of the Mannesman Hüttenwerke for the distribution of lubricants, since in France standard colours have already been chosen for other fluids, e.g. oxygen. The only colour reserved for all lubricants, i.e. oils and greases, is yellow. It seems, therefore, that a code of simple geometrical drawings would be preferable.

Our committee has now established a classification for common oils, and we can supply the table* of these. The classification of special oils and greases is now being studied and special products will be considered later. When completed, the results of these studies will be made available.

Mr. **Jordan**: Dr. Griese mentions that the main purpose of lubrication is to avoid wear and with this we must all agree. In any reference we make to lubrication we imply bearing protection and wear reduction.

Dr. Griese then argues, if we understand him correctly, that since steels are so closely specified, why cannot we do the same with oils? We believe that there is still some danger in doing this but our knowledge of lubricants is growing so rapidly that there is no reason why this should not be our ultimate future objective.

The positioning of oil grooves in designing bearings is still greatly abused and our experiences conform very closely to those of Dr. Griese. There is every reason to condemn the positioning of oil grooves in the pressure areas of bearings. As Dr. Griese points out, there is no cause for bearing users to perpetuate the ' accident ' of Beauchamp Tower.

* "Cahier des charges pour la fourniture des lubrifiants," 6th edn., 1954, Commission Technique de la Lubrification, Charbonnages de France.

We are very interested in Mr. Wunsch's remarks and commend the trouble he has taken in plotting our viscosity classification. Concerning the choice of international viscosity units we have no objection in principle to either the centistoke or the centipoise. It would appear that most authorities favour the centistoke unit as this is directly measurable by standard test procedures, but as the two are directly related by density (or specific gravity) no objection could seriously be raised to either. The point at issue is that an acceptable scientific unit is essential for a universal understanding of lubrication design problems.

The contributions from Monsieur Desecures and Drs. Eisenstecken and Griese indicate the universal awareness of the problems associated with the classification of lubricants in industry. We have illustrated the way in which we believe this question might be viewed, and our operating experiences over the past few years indicate that the benefits of this approach can be extensive.

Part II

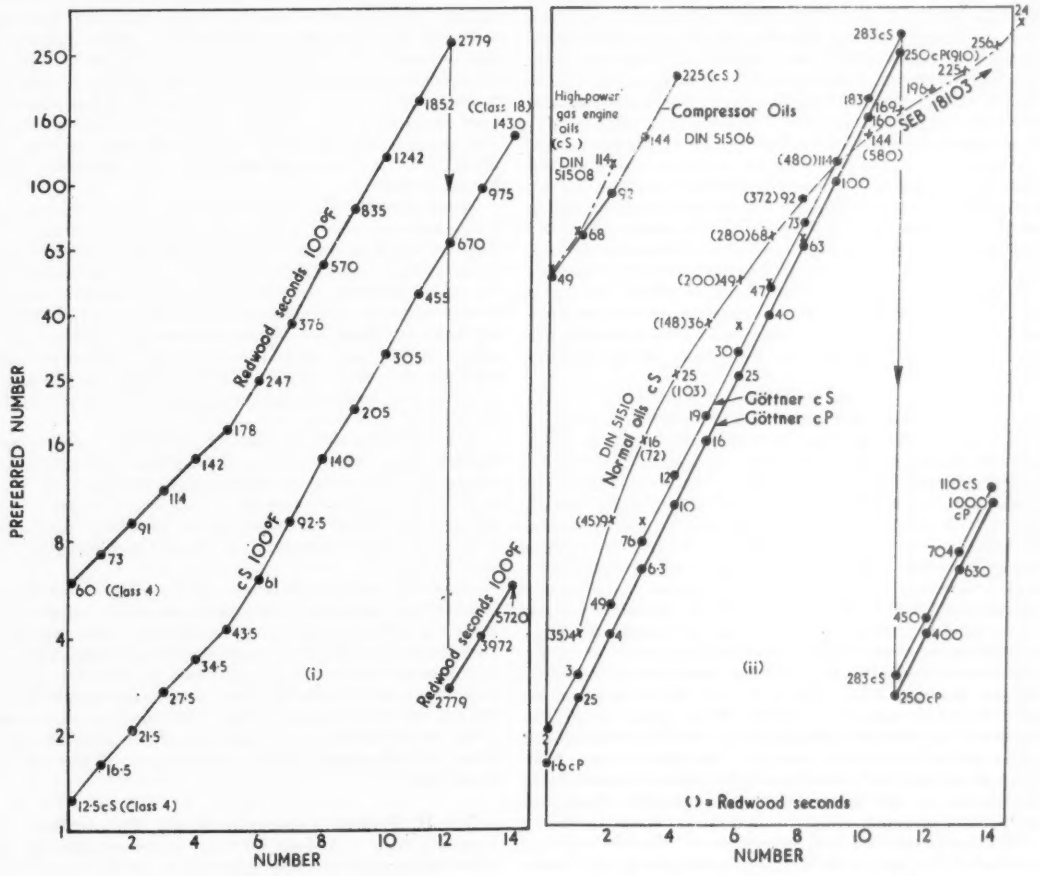
Mr. S. L. Norton (Davy and United Engineering Co., Ltd.): I must first of all congratulate the authors on their excellent paper in which they have stressed the importance of lubricant application. I feel that the development of efficient means of supplying and controlling the lubricant has, without a doubt, been the key to the progress made in steelworks lubrication in recent years.

Mr. Jones's outline of the various types of oil and grease systems available illustrates that one of the important tasks of a steelworks lubrication engineer has been to apply modern lubrication methods to existing plant.

Today the majority of mill manufacturers are aware of the importance of lubrication and therefore plan for it in the early stages of mill design. The demands for faster and more continuous production methods have made it essential that automatic lubrication is incorporated in all large steel projects.

This fact should help to solve at least one of the problems of the steelworks lubrication engineer, i.e. of having to fit lubrication systems on plant which has already been installed. Mr. Jones's review of the lubrication of blast-furnace equipment is of interest as very little information has been written on this subject or type of application.

I should like to comment on one or two points arising out of the paper. First, I note that two types of oil systems are shown, the gravity type and the direct pressure-controlled system. I have had experience of both kinds. I consider the gravity type to be somewhat obsolete, with no advantages over the direct pressure-controlled system, which has been proved the most



(i) According to Jones and Jordan

(ii) According to Göttner (German standards)

Fig. H—Classifications of viscosity

reliable method of applying oil to gears and bearings. I should like to hear Mr. Jones's views on the point.

Second, Mr. Jones refers to magnetic filters being installed in the main oil-return lines. While, no doubt, it may be the ideal position for such a filter, I would not consider it good practice to risk a restriction in a gravity return line. I can visualize a build-up of oil caused by a pressure-drop across the filter, which may be due to an increase in oil viscosity or a build-up in deposits. Therefore, wherever possible, it is preferable to install filters on the supply lines rather than on the suction or return.

Third, following on Mr. Jones's reference to pipe scale, it may be of interest to note that a new process has been adopted in this country of pickling *in situ*. This process is now being used on both lubrication and hydraulic pipework for the removal of scale caused by the initial welding and bending during installation. This process has the advantages of saving in both cost and time.

Finally, could Mr. Jones give any examples of the increase in life of mill bearings, gears, or screws by the application of modern methods or by the use of new types of lubricants.

Mr. **Jones**: Mr. Norton has raised the question of the use of direct pressure as opposed to gravity as a means of supplying lubricant to plant in general. Where the same system is used for the lubrication of both gears and bearings, and the gears are spray lubricated, then the direct pressure method has the advantage, but where bearings alone are involved, unless they are specially designed to operate hydrostatically, quantity rather than pressure is the controlling factor and this can be equally well met by either method. Certain plant, such as flywheel sets or fans of the size mentioned in the paper, has a considerable run-down time for which a reserve of oil must be available. When this reserve is provided by means of a gravity tank there will be very little change in the pressure head and the supply will remain reasonably constant. If, however, the direct-pressure system is used, a pressure vessel of considerably greater capacity than the corresponding gravity tank will have to be provided and the supply to the bearings will diminish as the pressure-head falls. Examination of the systems illustrated in the paper will show that they are essentially direct pressure with gravity reserve.

The question of the positioning of filters is a very vexed one. While the logical position for any filtering device is obviously as near as practicable to the point of possible contamination, this ideal can seldom be realized, mainly because few, if any, systems can afford the loss of head that fine filtering imposes in the gravity return lines. We have found that fitting magnetic filters affords a partial solution to this problem. The filters employed offer very little resistance to flow; after a week's working the pressure drop across them rarely approaches 1 lb/in^2. In their capacity as filters they serve a very useful purpose in protecting the pumping equipment from the worst of the abrasives, ease the load on the fine filters installed in the delivery lines, and by examining the material they collect, a very good idea can be formed of the amount of wear taking place or of the ingress of the ferrous contaminants invariably associated with iron and steelworks practice. Another point to bear in mind is that they arrest not only ferrous material but also many of the other polar contaminants found in lubricating systems.

Pickling *in situ* is a new process to us. We have always insisted in the past on pickled pipes being used for all new lubricating systems but certain well-known machine makers take a good deal of persuading to do it. With our latest turbines we had to insist that the pipes should be pickled before being erected. The pipes come capped and are not uncapped until in use, but we still get adventitious material in, and that is why we like to give the system a good flush before the working oil is put in.

The advantages of, and savings to be derived from modern systems are fairly obvious, though it is not easy to give figures. On our 42-in. cogging mill every set of the present white-metal bearings has done a million tons or more, and this is largely because they are fitted with a modern lubricating system. Much of it is attributable, of course, to the design of the bearings, and an equal amount to the care which the maintenance people show in assembling them. We have recently fitted a small circulating system to the mill screws on that mill, and with quite a common bronze nut the overall rate of wear over the last eight months has been about 0·001 in./week.

Mr. **B. R. Pyke** (Farvalube Ltd.): In the early part of this extremely interesting paper, reference is made to Mr. Knight's paper of some ten years ago. In opening the discussion on that paper, Mr. L. D. Colam was, I believe, the first in advocating the appointment of lubrication engineers in the British steel industry. It is, therefore, of particular satisfaction to see the progress which has been made in this direction since then. It will be readily conceded that the contribution which the lubrication engineers have already made to their companies' economies is now self-apparent and has been acknowledged by their confirmation in office and by the appointment of others elsewhere. Those of us who are concerned in this particular field will all agree that on a major project of any nature, the firm which has a lubrication engineer is considerably simpler to deal with as he can provide much of the basic information required, thereby saving his own company and ourselves many hours of work.

We would like to make two main points. Centralized lubrication can be said to have been born in the U.S., but we now find ourselves in the satisfactory position of being able to exchange lubrication ideas with the U.S. on an equal basis. In considering U.S. data, it must be borne in mind that there is a country naturally rich in oil that is, therefore, relatively cheap. U.S. ideas on consumption and life of oils must, therefore, differ considerably from our own which must be taken into account in determining the design of our lubricating systems.

U.S. greases are, generally speaking, considerably lighter than our own and data from abroad on pipe sizing can be extremely misleading. We suggest, therefore, that anyone interested in plant design from a lubrication point of view should carefully investigate any information received from abroad and check on U.K. experience.

Secondly, we should like to endorse the point already made that successful lubrication involves collaboration between at least four groups of people: those who build the plant (the machine builders), those responsible for the design of the bearings, those responsible for the supply of the lubricants, and those responsible for the supply of the systems. This collaboration at an early stage can result in the realization of the ultimate aim of them all: the satisfactory performance of the machine concerned.

Mr. **H. P. Jost** (Centralube Ltd.): The authors have stated a very good case for lubrication engineering, and their arguments are strengthened by general knowledge of their own very valuable work in this sphere.

In a modern steelworks, and particularly where there is a very good lubrication engineer, it is possible to do

many things which may not be advisable to be copied in the majority of the older steelworks where conditions are far from ideal, where the plant is sometimes very old, where labour is not always co-operative, where conditions are generally very rough and ready, yet where in many cases the output is excellent.

When considering lubrication engineering in such steelworks, the problem must, in my view, be approached through the eyes of the mechanical or works engineer. In fact one might go as far as to say that if the mechanical engineers in steelworks had the knowledge of lubrication engineering which they should have, and which they ought to have received as part of their training, there might be no need for a specialized lubrication engineer in most steelworks except on new constructions and for the collection and dissemination of information. Unfortunately, however, in the training of works and mechanical engineers, the subject of lubrication engineering is notable by its absence. In my view, its incorporation is a most urgent requirement.

In the selection of lubrication equipment, the following three basic principles ought to be in the engineer's mind. They are simplicity, sturdiness, and reliability. For instance, as Mr. Jones mentioned, it may be a good idea to put the distributors or dividers of a line system in a box so that their small moving parts are protected against dust and dirt. However, I have found that in conditions of dust and dirt it is very much better to have no dividers at all and use direct-feeding lubrication equipment, i.e. lubrication equipment where an amount of lubricant is fed directly and positively by the lubricator to the point of application, without the introduction of any dividers and operating without springs, valves, solenoids, etc. For installations with up to about 36 points, direct-feeding lubricators have generally been preferable to line systems; however, for larger systems direct feeding has in the past meant a very large number of pipes. With the new centralized direct-feeding system, however, where a number of direct-feeding pumps are each being charged by a centrally positioned master feeding-pump, this objectionable feature has to a certain extent been removed.

Messrs. Jones and Jordans' approach to classification of lubrication systems is an excellent beginning towards the selection of types of lubrication equipment, not by make or salesmanship of the makers, but by the operating conditions of the bearings to be lubricated. An attempt to carry this theme further is shown in Fig. *I* which relates to total loss systems (grease lubrication) only, but is capable of extension to other systems. The main division on the grease lubrication side is between line systems on the one hand and direct-feeding systems on the other. Basically, the line systems lend themselves very well to long lines with a large number of points to be fed, usually intermittently. Direct systems with a direct feed from the lubricator to the points, without any distributors or dividers with moving pistons and plungers in them, or the centralized direct systems with a number of direct-feeding lubricators, all of which, however, are fed by a central master pump, have the advantages of functioning in extremely unfavourable conditions of dirt, bad handling, neglect; they are also able to handle very much stiffer lubricants, which in many cases would obviate the use of greases which are not the most suitable for the purpose but which are utilized solely because the right type of grease cannot be pumped.

For plain bearings, particularly those heavily loaded, and for continuous lubrication, direct systems are usually the best, while for intermittent application, a line system may be preferable. Where it is possible to drive the lubrication equipment from the parts to be lubricated (as on a crane where the long travel can be used, or on a

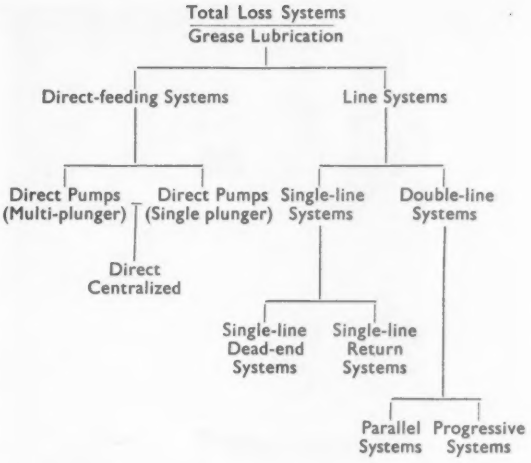


Fig. I—Suggested classification of lubricants according to operating conditions of bearings

shear) the direct system lends itself by design and adaptation to sound and reliable lubrication. A lubricator which is coupled to the machine to be lubricated operates with, and in proportion to, the speed of operation of the machine, i.e. the amount of lubricant depends on the amount of work which is done by the bearing.

My own experience of the lubrication of heavy steelworks equipment, has led me to prefer the direct-feeding system to the line system, wherever this can be practicably employed.

The factor of weight should not be overlooked when lubrication equipment is selected. Whilst weight alone does not make reliable lubrication equipment, for steelworks use it is usually true that without weight there will not be a reliable lubricator. Figures *J* and *K* show two types of heavy lubrication equipment supplied to steelworks, one of the direct-feeding type with a 3-cwt container, the other of the direct-feeding centralized type, and the latter can be literally buried under dirt and dust yet still operate satisfactorily.

In conclusion I would like to support Mr. Pyke in his plea to be careful of information originating from abroad. This is particularly so when this information comes from the other side of the Atlantic. As Mr. Harber said recently, both U.S. and German lubrication practice have much to teach us, but he felt perhaps a marrying of the two to suit British conditions might give the right answer. In my view, the ideal answer will be the engineer's answer, and a simple and 'weighty' one it will be.

Mr. Jones: We agree with Mr. Pyke's remarks concerning the need for care in selecting pipe sizes for mechanical grease systems. We have operated this type of equipment for a considerable number of years without running into serious trouble with undersized grease lines, although many of the pipe sizes used are smaller than those recommended by Mr. Pyke's company; indeed with the improved pumpability of the more modern greases the choice of pipe size is more often conditioned by the need for robustness to withstand rough usage than by considerations of pressure loss.

Mr. Jost has divided mechanical grease systems into two broad classes which he has called direct-feeding systems and line systems. It was laid down very early on in our standard code of lubrication practice that wherever possible the rate of feeding lubricant should be

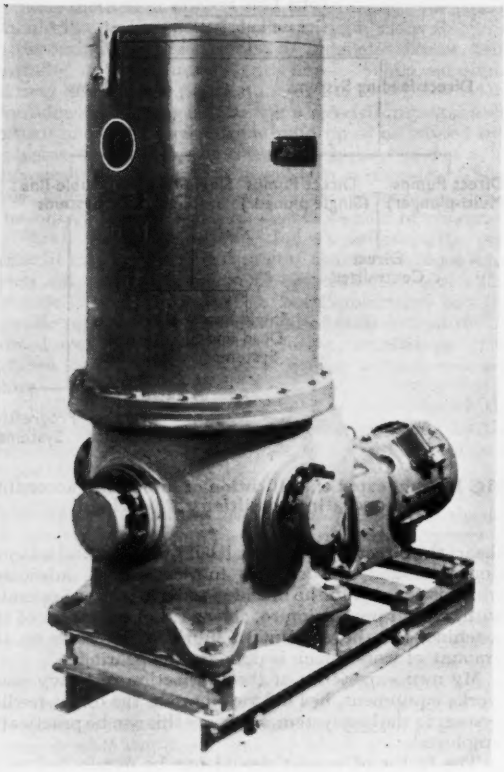


Fig. J—Direct-feeding lubricator with 36 outlets for use on rolling mill; capacity 3½ cwt grease

related to the working of the machine, and that one of the most effective ways of doing this was by means of what Mr. Jost calls direct-feeding systems. The main weakness of these systems is the large number of small diameter lines involved and as already pointed out, this type of pipework is extremely liable to damage in the rough and tumble atmosphere of a steelworks and so constitutes a very real hazard. Line systems, on the other hand, are very robust, 1½ to 2-in. mains often being used; and because of this they are often chosen in preference to direct-feeding systems. This further emphasizes the fact that in choosing a lubrication system for a particular application, it is not only necessary to consider the requirement of the particular machine but also its location and environment.

Mr. **R. A. Lake** (Richard Thomas and Baldwins Ltd.): I do not agree with the authors' suggestion that we should have a separately pumped oil-circulating system on the crab of an E.O.T. crane. The practice developed in automative and traction work of mounting all slow-speed shafts in anti-friction bearings which, when efficiently sealed need little lubrication and infrequent attention, should also be applied to the overhead crane.

The higher-speed shafts should have their bearings built into, and forming part of, the gearboxes, and the bearings can be lubricated by gear oil. As this system works successfully on lorry, tractor, and rail traction gearboxes there is no reason why it should not be successful on the less heavily stressed gearboxes of E.O.T. cranes. An occasional oil change, to keep down the concentration of suspended matter in the gear oil, is usually regarded as less trouble than the maintenance and filter-cleaning of a separately pumped oil-circulating system, to say nothing of the vulnerable pipework associated with the latter.

We have recently been impressed by the efficacy of the magnetic plug as a means of removing suspended metallic particles from gearbox oil.

Mr. **Jones**: With regard to Mr. Lake's remarks concerning the suggestion that overhead cranes could benefit by having a built-in circulation system, we would point out that although we have operated cranes of the type he describes, in spite of all the precautions we have been able to take we still have gear failures which can be attributed to lack of proper lubrication when the crane is being subjected to the limited movements encountered in such operations as ingot teeming, etc. Another continual source of complaint is the incidence of used grease falling from the crane, much of which could be eliminated by the use of a properly designed oil-circulating system.

Mr. **Jordan**: Mr. Norton has rightly emphasized the relationship between the complexity and size of modern lubricating systems on rolling mills, and the size of the mill itself. We must agree that for the lubrication systems to fulfil their function adequately, a great deal of civil engineering is required to provide oil cellars and service trenches. If we use the overall cost of the equipment and the civil engineering as a measure of the importance of lubrication to the installation of a modern rolling mill, then it must rank relatively highly in the complete scheme.

Mr. Pyke mentioned the difference in attitude between the Americans and ourselves and referred to the fact that lubricants are abundant and cheap in the U.S.A. This is quite true but nevertheless the U.S. lubrication engineer is much more serious than his counterpart in this country, in collecting lubricant consumption data and using the cost of his lubricants as a measure of the success or otherwise of his activities. On the question of ' thin ' greases it is important to remember that it is extremely difficult to interpret grease consistency in terms of its pumpability. It is therefore dangerous practice to relate the N.L.G.I. rating to the manner in which a grease can be pumped.

Mr. Jost gave the three requirements for a lubricating system as simplicity, sturdiness, and reliability. These are certainly features which should be borne in mind when investigating the systems available on the market,

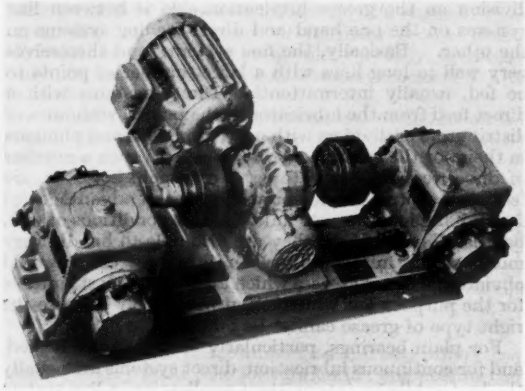


Fig. K—Main unit of direct feeding centralized lubrication system for 42-in. cogging mill; weight of unit 5½ cwt

but in assessing the requirements for a system we should take measure of the adaptability of the lubricating equipment to the plant we are considering and, above all, the ability of the equipment to pump successfully the lubricant which has *first* been selected for the plant.

Concerning Mr. Lake's comment about the use of magnetic plugs in enclosed gearboxes we would give a word of warning. Many gearbox manufacturers appear to consider the question of indicating the oil level as an afterthought and discover that the only way of doing this is via the drain-plug hole. Into this they insert a **T**, the riser of which is fitted with a level rod. The conventional drain plug is now replaced by a magnetic type which by collecting wear material from the box eventually causes a restriction at the base of the level indicator. The result is that gearboxes equipped in this manner become dangerously low in oil while the level indicator continues to show an adequate quantity. It is safer to fit level indicators in a position quite separate from the drain plug.

Mr. **J. Gardner,** A.M.I.Mech.E. (Centralube Ltd.): I refer to two applications which, no doubt, limitation of space prevented the authors from referring to, but which I feel will be of considerable interest to steelworks engineers in general. The solution of both problems is obtained by means of the type of system shown by the authors in Fig. 4 of their paper, but both are special adaptations.

The first problem is that of crane wheel and crane rail wear. Throughout the years many attempts have been made to solve this problem, which is prevalent in most steelworks, particularly in those where the buildings themselves are subject to subsidence, and might lead to wear such as that reported by Scott Maxwell,* shown in Fig. *L*.

Many attempts to solve this by various sticks and other means have been made. Reports have often been issued that tests were promising. In the last 18 months, however, two complete solutions have been found. The first of these is a special crane-rail compound based on molybdenum disulphide and made by K. S. Paul (Molybdenum Disulphide) Ltd. The second is by mechanical crane-rail lubrication.

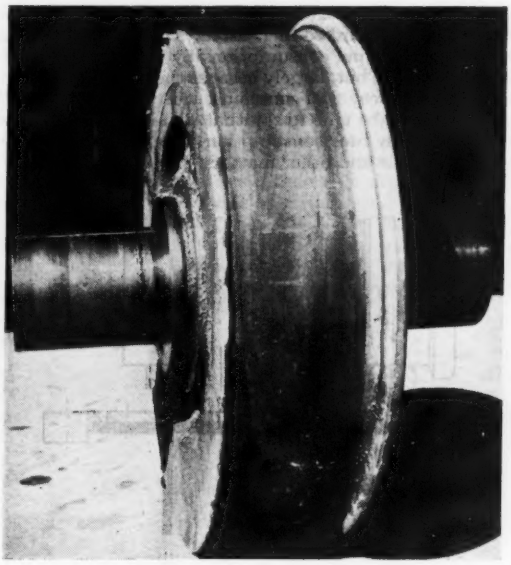


Fig. L—Wear on crane wheel

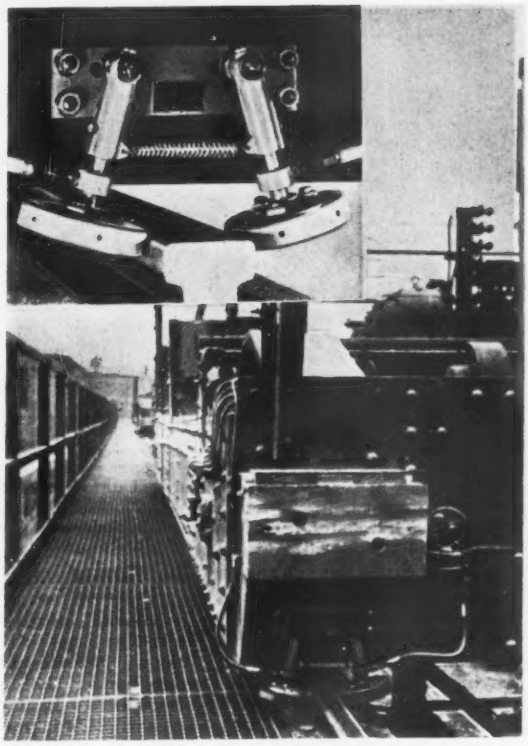


Fig. M—Direct-feeding mechanical lubrication (oil) of crane rail

In the latter case (Fig. *M*) the lubricant is fed from a direct-feeding lubricator to two applicators, each of which has two felts, the latter rolling along the edges of the rails. As the crane moves and as the long-travel shaft actuates, the lubricant is fed to the hard felt pad, and from there to the rail. The amount of oil used is extremely small, about 4 g/h of long travel operation, which in many cases means per shift, i.e. even in the case of a 20-h day, for a total cost of two or three shillings per week, crane-rail and wheel wear can be almost completely eliminated.

It is very interesting to note that this type of crane-rail lubrication is even considered on cranes which, instead of flanges, have constraining roller bearings, because when the crane starts a slight tilting motion takes place, resulting in the ' digging-in ' of the edge of the roller race into the side of the rail.

The second problem that was solved by special adaptations of direct-feeding equipment, is the lubrication of palm ends and slippers. In this case the direct feeding lubricator is attached to the spindle and revolves with it. A cam, which is fastened to the bearing, actuates a reciprocating arm which in turn drives the lubricator, ejecting grease into the various parts of the slipper continuously (Fig. *N*).

Spindle speeds have been a limitation to the develop-

* I. S. Scott-Maxwell: " Some Mechanical Maintenance Troubles on Long-travel Drives "; Report of B.I.S.R.A. Conference on Steelworks Electric Overhead Travelling Cranes, Harrogate, 1955, pp. 24–36.

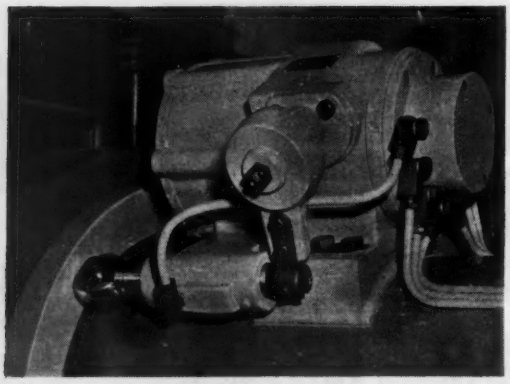


Fig. N—Direct-feeding mechanical lubrication (grease) of slipper

ment on these lines and so far lubricators cannot be used on speeds greater than 450 rev/min. The lubricant used in palm-end lubricators must be carefully selected and should usually have anti-fretting properties.

Mr. **C. M. Wroe** (Richard Thomas and Baldwins Ltd.): Lubrication engineers should not only be content to supply the correct grade and quantity of lubricant to a bearing; they must also try to ensure that it stays there by means of good sealing. Good sealing will also prevent the ingress of scale and other foreign matter that is always present in a steelworks atmosphere. In my opinion, more bearings are damaged as a result of ingress of foreign matter rather than as a result of breakdown in the supply of lubricant.

The **Chairman**: One or two aspersions have been cast on flexibles. I was at a recent conference on hydraulics at which we were assured that modern flexibles would stand pressures up to 5000 lb/in^2 for a long time. I should be very interested to hear comments from anyone who has tried them.

Mr. **Jones**: While we try to eliminate the use of flexibles wherever possible, there are many places where their use is unavoidable. With ordinary care we have found that the modern flexible pipes are very good and the damage they suffer on blast-furnaces cannot be in any way attributed to the flex itself but rather to mechanical damage brought about by the conditions under which they are used.

We have nothing to add to what Mr. Gardiner has said. We are very familiar with crane and palm-end lubricators but still regard them as part of one or other of the systems outlined in the paper. There is another approach to crane-wheel and flange lubrication which some people have been exploring, not without success, and that is a surface treatment of the wheels to prevent wear. We can deal with the wheels satisfactorily, but we are still left with the rails, which are another problem. Probably it is necessary to lubricate crane rails. On steelworks railways, which have very sharp curves, we have found that by putting a rail lubricator on the curves we have increased the life of the rails there very considerably.

We agree with Mr. Wroe that sealing is a very important matter, and it is one which is always with us in steelworks. It is always a problem to keep lubricant in a bearing and dirt and water out of it. If, however, we were to go into the question of sealing we could occupy the whole of another session such as this without exhausting the possibilities of the subject.

Mr. **D. J. Laycock** (Morgan Crucible Co., Ltd.): Rail and wheel lubrication can be considered from the point of view of using wet or dry lubricants. As regards dry lubrication, the application of a very soft graphite rod has been tried and ruled out because of its high rate of wear. My company is now experimenting with a composite rod of very soft artificial electrographite encased in a hard carbon tube, the latter limiting the rate of wear. All that will be required will be an occasional replacement of this composite lubrication stick which will cut down friction and reduce the wear on the wheel flange. The field experiments are promising and it is hoped that they will lead to a solution of the problem without any mechanical complications.

The **Chairman**: A point that has arisen from this discussion is that there is an obvious need for some form, and preferably an international form, of standard. We should all consider how best this can be brought about and whose job it is likely to be. I have suggested to the head of the Plant Engineering Division of B.I.S.R.A. that the new Engineering Techniques Committee, of which I am Chairman, should at their next meeting consider what steps should be taken by B.I.S.R.A.

Obviously this subject is very much wider than even the iron and steel industry. I have also talked with people from the oil industry and other industries, and it is unanimously agreed that it is time to stop the nonsense of various units. One which comes to mind is the U.S. gallon, which, unlike most things in the U.S.A. is rather smaller than the usual gallon! There is at least one positive suggestion for action, and I hope that others at this meeting will think about the subject, and perhaps we might eventually hold a meeting, possibly in Geneva, and discuss how we can talk in terms of some commonly agreed units.

Another thing which has come out of this discussion is the importance of recognizing the different backgrounds in different nations. One speaker said that oil is cheap in the U.S., while another speaker was impressed by the amount of work done by U.S. operators in recording information on oil consumption and so on. He did not say whether or not any use was made of the information! There has been an exact parallel in the attitude of our industry with regard to fuel. In days gone by, when fuel was cheap, our fuel consumptions by modern standards were prodigious, but, largely because the price went up, we have become very fuel-conscious, with the result that I think it would be true to say that we are second to none in economy in fuel consumption. So it must be with lubricating oils and other matters.

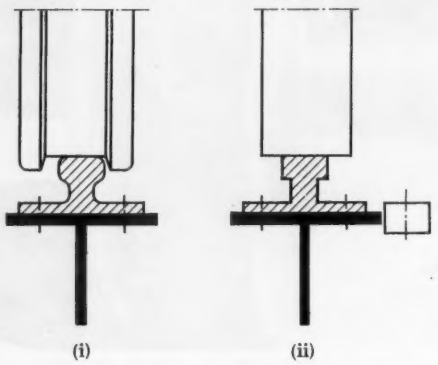


Fig. O—Modification of crane wheel

CORRESPONDENCE

Mr. **H. R. Goldie** (K. S. Paul (Molybdenum Disulphide) Ltd.) wrote: It was with great interest that I read the classification of lubricants by Messrs. Jones and Jordan. One item which they have not dealt with, no doubt because of limitation of space, is the use of the solid lubricants, and amongst these from the steelworks point of view perhaps the most important one is molybdenum disulphide.

Molybdenum disulphide is a powder which does not only act in the manner of a lattice material (e.g. graphite) but also causes metallurgical change of the surface which facilitates plastic deformation of surface irregularity under pressure without actual metal-to-metal contact. In general I would classify two groups of usage in iron and steelworks.

Group 1—This largely confines treatment to an initial application of MoS_2 as a means of safely overcoming the running-in period, i.e. to prevent hard-on direct contact of highspots through separating them effectively by a MoS_2 skin. In many cases, its high film strength has proved to give ample safety margins even under very severe conditions, e.g. screw-downs.

Once the high spots had been ' ironed down ' under operating pressure, protected by the film, the much lower pressures resulting from areas of contact thus increased up to twenty-five fold, would bring the job down to within the capabilities of conventional lubricants applied and replenished in quantity, e.g. phosphor-bronze mill bearings.

Before beginning the the running-in process, I suggest that the effective bearing areas are seldom more than 50% of the area designed to sustain the load. The vastly higher pressures thus involved in the form of point loads lead to the common phenomenon of welding-up and subsequently tearing apart of high spots.

Once the surface condition is seriously disturbed thereby, it remains a source of trouble throughout the life of the plant which it is almost impossible to cure, i.e., the rate of wear will be abnormally high, no matter what lubrication palliatives are adopted.

If, on the other hand, the mating process can be divested of its ' hard-on ' bulldozing features by means such as MoS_2, the gain appears to make itself felt by a markedly lower rate of wear long after the initial treatment.

The operating pressure, furthermore, appears to be an effective means of burnishing the MoS_2 particles into the surface, thus achieveing a close and fairly enduring bond. Details of the extent to which metal surfaces are prepared before the application of MoS_2 as a matter of standard practice (other than degreasing with trichlorethylene) would also be of interest.

Group 2—Jobs which will benefit by the MoS_2 film being replenished, either by individual application of a highly concentrated MoS_2 paste to, say, heavily loaded open gears, or by means of sustaining it through continual feed of minute quantities of MoS_2 suspended in oil carriers in colloidal or semi-colloidal form.

I understand that the use of MoS_2 has gained considerable ground in German steelworks practice, and I would be glad to hear whether there is general agreement with the rather arbitrary headings of ' pre-treatment only,' ' continual feed during operation to keep the MoS_2 skin in being,' as well as to hear of job details where both features are effectively pursued.

When continual feed of MoS_2 to bearing areas is resorted to, I have found it expedient to take care that only small quantities of MoS_2 are applied, sufficient to keep the film in being, to avoid a surplus of solids.

Any indication of the means adopted to control this limitation mechanically, would be of interest.

The **Authors** wrote in reply: We would agree in principle with Mr. Goldie's general classification of usage for molybdenum disulphide. However, as there is a whole field of drycoatings and surface treatments available for investigation we would suggest the terms ' pre-treatment ' as applying to applications of compounds and surface coatings before assembly, and ' continued treatment ' as applying to follow-up additions of the same materials to pre-treated surfaces. The continued treatment phase need not necessarily be of the ' continual feed ' type but can be intermittent as dictated by operating conditions.

We have only limited experience of the use of molybdenum disulphide but where we have used this material, particularly in assembly work, the results have been encouraging.

In connection with Mr. Goldie's reference to how to control the feed of further additions of molybdenum disulphide in the continued treatment phase, we do not apply this by mechanical lubricator as a concentrate. Where dry films are desired, the molybdenum disulphide is applied as a colloidal suspension in spirit. In oil-lubricated applications the molybdenum disulphide is in the form of a colloidal suspension which is diluted by addition to the oil in the system. Likewise, with grease-lubricated bearings, molybdenum disulphide powder is mixed to paste form with the grease in the system. In these ways, by progressive dilution, very small quantities of molybdenum disulphide are actually fed to the bearings.

Dr. **Griese** wrote: I should like to add a comment on rail wear. It is part of the task of the lubrication engineer to see whether there is not another way to deal with the problem. Normally there is a flanged wheel, as in Fig. *O* (*i*), but in Germany it is believed that the best way to avoid wear on the flange is to cut it away as in Fig. *O* (*ii*). It is then not necessary to lubricate as no wear takes place. In this way we can change from slide friction to roller friction. Nearly 100 modern cranes in Germany are without flanges, and they are very satisfactory.

N E W S

Announcements and News of Science and Industry

THE IRON AND STEEL INSTITUTE

Joint Meeting in Sheffield

The Iron and Steel Institute is holding a Joint Meeting with the Sheffield Metallurgical Association and the Sheffield Society of Engineers and Metallurgists in Sheffield on Thursday, **28th November,** at 2.15 p.m. Four papers, details of which were given in the September issue of the *Journal* (p. 55), are being presented and discussed. The meeting is being held at the University.

Following the Joint Meeting, the Tenth Hatfield Memorial Lecture is being delivered in the Firth Hall of the University at 6.30 p.m. The lecturer will be Professor Paul Bastien, Director of Research, Société des Forges et Ateliers du Creusot, who has chosen as his subject "The Mechanism of Formation of Banded Structures in Steel." Applications for tickets for the Lecture should be sent to the Registrar, The University, Sheffield 10.

NEWS OF MEMBERS

Professor **Albert Portevin** has been appointed an Honorary Commander of the Order of the British Empire, in recognition of the great services he has rendered to Britain. Professor Portevin was awarded the Andrew Carnegie Gold Medal in 1909, and the Bessemer Gold Medal in 1935; he was elected an Honorary Member of the Institute in 1946. A biographical note appeared on p. 17 of the May, 1956, issue of the *Journal*.

Mr. **K. S. Aldersley** has left Hopkinsons Ltd., Huddersfield, to become Chief Metallurgist and Assistant Foundry Superintendent to Maritime Steel and Foundries Ltd., New Glasgow, Nova Scotia, Canada.

Mr. **R. H. Brown** has joined the British Steel Castings Research Association as a senior investigator in the Plant Engineering Section.

Mr. **E. W. Colbeck** has been elected a Member of Council of the British Steel Castings Research Association.

Major **J. C. Dunlop,** M.C., has been appointed Works Director with J. J. Habershon and Sons, Ltd.

Dr. **T. P. Hoar** has been elected President of the Institute of Metal Finishing for 1957–1958.

Mr. **J. H. Icke,** jun., has joined Railko Ltd. as Technical Sales Engineer.

Mr. **D. Kerry** is now Chief Engineer at the Bilston works of Stewarts and Lloyds Ltd.

Mr. **J. W. Lambert,** who was recently appointed Works Manager of Union Carbide Ltd., Alloys Division, has received the City and Guilds of London Institute Insignia Award in Technology.

Mr. **J. Leja** has been appointed Assistant Professor of Metallurgy at the University of Alberta, Edmonton, Canada.

Mr. **I. N. Mathur** has taken up an appointment as assistant in the Blast-furnace Department of Klöckner-Georgsmarienwerke AG, Georgsmarienhütte, Germany.

Mr. **A. B. Mitra** has joined the Loewy Engineering Co., Ltd.

Mr. **C. Moore** has been awarded the degree of B. Met. at Sheffield University and is now working in the Research Department of Metropolitan-Vickers Ltd.

Mr. **J. Mowat** has been elected a Member of Council of the British Steel Castings Research Association.

Dr. **S. R. Pramanik** is now Technical Officer with Hindustan Steel Private Ltd., Rourkela, India.

Dr. **N. L. Samways** has joined the Research and Development Section of the Jones and Laughlin Steel Corporation.

Mr. **Carl Sebardt** has left Sandvikens Jernverks AB to join Oxelösunds Järnverks AB.

Mr. **R. W. Shapton** has been appointed Chief Metallurgist of Rotax Ltd.

Mr. **L. R. Stanley** has left Stewarts and Lloyds Ltd. to join John Summers and Sons Ltd.

Mr. **R. G. Walmsley** has joined Birfield Ltd. as Director and General Manager of their subsidiary company Railko Ltd., following the closing down of the Railko Department of Small and Parkes Ltd.

Dr. **C. M. Wayman** has been appointed Assistant Professor of Metallurgical Engineering at the University of Illinois.

Monsieur **J. Wurth** has been appointed Directeur Général de la Sidérurgie of the S.A. Cockerill-Ougrée and is now in charge of all the iron and steelmaking activities of the Company.

Obituary

Mr. **Louis H. Derrer** (*elected* 1946), of Saulte Ste. Marie, Ontario, Canada.

Mr. **Wilfred Marsh Gillott** (*elected* 1913), of Sheffield, on 24th July, 1957.

Mr. **G. W. Preston** (*elected* 1938), of Radlett, Herts., on 17th June, 1957.

CONTRIBUTORS TO THE JOURNAL

W. H. Glaisher, B.SC., A.I.M.—Member of the Management Courses Staff, British Iron and Steel Federation.

Mr. Glaisher received his technical education at the Sir John Cass Technical College, graduating in 1939. After some years with the British Non-Ferrous Metals Research Association, he joined the Steelmaking Division of B.I.S.R.A. in 1946, to work mainly on problems connected with ingots and ingot moulds. He took up his present position in 1956.

W. H. Glaisher

R. A. Granville

W. J. Jackson

G. M. Michie

A. Sigalla

R. A. Granville, B.SC., A.INST.P.—Head of Fluid Dynamics Section, Physics Department, British Iron and Steel Research Association.

Mr. Granville was educated at Eltham College and Leeds University. He joined the Fuel Technology Section of the B.I.S.R.A. Plant Engineering Division in 1954, and transferred to the Fluid Dynamics Section of the Physics Department in 1954, becoming Head of the Section in the following year.

W. J. Jackson, B.SC., M.SC.(ENG.), A.R.I.C., A.I.M.—Head of Physical Metallurgy Section, British Steel Castings Research Association.

Mr. Jackson was born at Walsall in 1924 and educated at Queen Mary's School. He attended Birmingham University from 1942 to 1943, and served in the R.A.F. on ground radar systems from 1943 to 1947, before returning to the university to complete his course in industrial metallurgy, graduating in 1950. He then joined the research staff of the British Oxygen Co., Ltd., and attended the Sir John Cass Technical College as a part-time student, where he was awarded the degree of M.Sc.(Eng.) in physical metallurgy. Mr. Jackson joined the production staff of Henry Wiggin and Co., Ltd., as Technical Assistant in 1952, and joined the research staff of B.S.C.R.A. two years later. He was appointed to his present position in 1956.

Hope Lubanska—Physics Department, British Iron and Steel Research Association.

Mrs. Lubanska, who was formerly a teacher, joined the research team of Dr. P. O. Rosin and Dr. H. R. Fehling at the Imperial College of Science and Technology in 1942 after passing the London University Intermediate B.Sc. examination. She was engaged there on experimental work on petroleum fuels for flame throwers until the end of the war, when she continued as research assistant at the Dr. Rosin Industrial Research Laboratory at Wembley. Since 1950 Mrs. Lubanska has been a member of the Fluid Dynamics Section of the B.I.S.R.A. Physics Department, where she has been engaged chiefly on the use and development of model techniques in open-hearth research.

H. S. Marr—Steelmaking Division, British Iron and Steel Research Association.

Mr. Marr was born in 1931 and educated at King Edward VII School, Sheffield. He joined the B.I.S.R.A. Steelmaking Division in 1954, and is at present studying for an external B.Sc. degree of London University.

G. M. Michie, M.A., A.INST.P., A.I.M.—C. A. Parsons and Co., Ltd.

Mr. Michie was born in Newcastle-upon-Tyne, and educated at the Royal Grammar School there and at Emmanuel College, Cambridge, where he graduated in the Natural Sciences Tripos in 1939. After a period as a student apprentice in the metallurgical research laboratories of the British Thomson-Houston Co., Ltd., Rugby, he joined the technical staff of the Penistone steel and bronze foundries of David Brown and Sons (Hudd.) Ltd. For some years he was responsible for the company's X-ray laboratories and other non-destructive testing services, and when he left in 1950 to join the British Steel Castings Research Association he was senior research metallurgist at the Penistone works. With B.S.C.R.A. Mr. Michie was responsible for the Association's activities in the fields of physical metallurgy, non-destructive testing, and industrial health. He left the Association in 1955 to join his present company, where he is engaged on metallurgical problems related to the design of nuclear power plant for the civil programme.

A. Sigalla, B.SC., A.C.G.I., GRAD.R.AE.S.—Senior Scientific Officer, Physics Department, British Iron and Steel Research Association.

Mr. Sigalla was born in 1927 and educated at St. Joseph College, Istanbul. He received his technical education at the Imperial College of Science and Technology. He joined the B.I.S.R.A. Physics Department in 1954, where he has been working in the Fluid Dynamics Section.

Hope Lubanska

H. S. Marr

IRON AND STEEL ENGINEERS GROUP

Meeting on Water Pollution

A two-day meeting on " Water Pollution in the Iron and Steel Industry " is being held in London on Wednesday and Thursday, **11th and 12th December, 1957.** Full details of the programme will be published in the November issue of the *Journal*.

EDUCATION

Chair of Metallurgy for Oxford

The establishment of a Professorship of Metallurgy at Oxford has been made possible by a gift to the University of £65,000 from Mr. Isaac Wolfson, Chairman and Managing Director of Great Universal Stores Ltd.

The gift, which was announced by the University on 9th August, will be formally accepted in Congregation on 22nd October, when it will be proposed that the new Chair shall bear the donor's name.

Mr. Wolfson's gift is an acknowledgment of the efforts, made for some years, to raise the status of metallurgical studies at Oxford. After Congregation has approved the formalities in connection with the gift, it is expected that the name of the first Professor will be quickly announced. It is considered likely that the Professorship will be allocated to Nuffield College.

Dr. W. Hume-Rothery, F.R.S., whose work at Oxford for more than 30 years has kept the study of metallurgy in Oxford well abreast of modern trends, is George Kelly Reader in Metallurgy. This readership was endowed by the Pressed Steel Company Ltd. in memory of a former Director of that company. Other industrial firms contributed more than a third of the cost of £100,000 of establishing in May, 1955, an honours course in the subject.

BRITISH IRON AND STEEL RESEARCH ASSOCIATION

International Deep Drawing Research Group

The problem of tests for assessing the suitability of sheet metals for deep-drawing and forming operations has been investigated in a number of countries, and it was felt that a measure of international co-operation would be beneficial. A meeting was therefore held in Amsterdam on 19th and 20th March of representatives of research organizations from Belgium, Chile, France, Western Germany, Holland, Sweden, and the United Kingdom.

As a result of this meeting, an informal co-ordinating body has been formed to promote co-operation in further research on deep-drawing and the cup-forming test on the basis of a unified test procedure. Information and unpublished reports on research in progress in individual countries will be circulated to members, meetings will be held from time to time to review progress, and occasional joint communications will be issued.

Membership of this body, known as the International Deep Drawing Research Group, is open to all organizations interested in furthering the aims of the Group. Enquiries should be addressed to the Technical Secretary, Mechanical Working Division, B.I.S.R.A., 11 Park Lane, London, W.1 (ref. I.D.D.R.G.).

Computers in the Steel Industry

A booklet entitled " Computers and Steel " has been published recently by B.I.S.R.A. which is designed to explain the operation of electronic computers and to indicate some of the ways in which they can be of use in the steel industry in particular. A Ferranti " Pegasus " computer is to be delivered to B.I.S.R.A. shortly, and it will be used for solving some of the complex problems encountered in the Association's technical research, and also as a pilot plant for demonstrating the potential commercial applications of the equipment.

NEWS OF SCIENCE AND INDUSTRY

Second Symposium on Sinter

The Second Symposium on Sinter, details of which were given in the April, 1957, *Journal* (p. 529), was held in Paris from 21st to 23rd May. It was attended by about three hundred participants from Europe, the U.S.A., and the U.S.S.R. Thirty-four papers were read, eleven of them from the U.K., covering many aspects of sintering and agglomeration.

Second World Metallurgical Congress

Technical and scientific sessions at the Second World Metallurgical Congress, which is being held in Chicago from 2nd to 8th November, will be divided into a number of groups. Group I includes iron and steelmaking, Group II continuous casting and degassing, Group III machining and forming of steel, Group IV carburizing and distortion, Group V welding and stress-relieving, Group VI testing and quality control, and Group VII education and research.

Over 500 scientists from 40 countries are attending the Congress. Each overseas visitor will have two U.S. counterparts throughout the Congress, acting as hosts and scientific associates.

24th International Foundry Congress

The 24th International Foundry Congress was held in Stockholm from 19th to 24th August; it was attended by over 1000 delegates from all parts of the world. A number of important technical sessions were held and visits were paid to foundries in Sweden and Finland. Post-Congress tours were held in Denmark and Norway.

Materials Handling Convention

The Materials Handling Group of the Institution of Production Engineers is holding a Convention at Leamington Spa from 28th to 30th October. The programme includes visits to factories in the Leamington and Coventry areas, and technical discussions. Application forms may be obtained from the Secretary, Institution of Production Engineers, 10 Chesterfield Street, London, W.1.

School of Welding Technology

A school of welding technology has been organized by the Institute of Welding which offers short intensive courses dealing with selected aspects of welding and with the application of welding to particular industries. Details may be obtained from the Secretary, The Institute of Welding, 54 Princes Gate, London, S.W.7.

New Steel Tube Plant

Stewarts and Lloyds Ltd. and John Summers and Sons Ltd. have made a preliminary arrangement whereby hot-rolled steel strip will be supplied by John Summers to an electric resistance weld tube plant to be installed by Stewarts and Lloyds adjacent to the Shotton works of John Summers. The tubes produced will be in the size range $6\frac{5}{8}$–16 in. outside dia., intended largely for export to the oil industry. The output of the Shotton works will be increased to make the necessary tonnage of strip available. The plant is expected to go into production early in 1960.

New High-temperature Alloys

Henry Wiggin and Co., Ltd., have introduced the name " Nimocast " to cover a range of high-temperature nickel–chromium-base alloys for use in the cast form. Those available include Nimocast 75 (formerly Nimonic C.75), 80 (formerly CC), 90 (formerly CB), 242 (formerly C.242), 257 (formerly MC.57), and 258 (formerly MC.58). Full details may be obtained from the Company, Wiggin Street, Birmingham 16.

Continuous Annealing for Tinplate

The continuous method of cleaning and annealing steel strip has been introduced to the U.K. for the first time with the putting into service of a new plant at the Velindre works of the Steel Co. of Wales Ltd. The new plant can handle tinplate gauge strip at 600 ft/min. It is 210 ft long and 53 ft high, and holds $\frac{1}{2}$ mile of strip in the furnace and cooling zone at any one time.

B.S.I.R.A. Open Days

Open days are being held at the laboratories of the British Scientific Instrument Research Association from 7th to 14th October. Applications should be made to the Director, B.S.I.R.A., Southill, Elmstead Woods, Chislehurst, Kent.

Ravenscraig Works

The new Ravenscraig works of Colvilles Ltd. is now in production. The coke ovens were lit on 3rd June and charged on 23rd July; the first push was on 24th July. After preliminary heating-up, the blast-furnace started on 2nd August, and the melting shop went into operation in mid-August; it has now reached full production.

Round Oak Centenary

To mark the centenary of Round Oak Steel Works Ltd., a luncheon was held at the Town Hall, Dudley, on 20th June, 1957. Those present included the Earl of Dudley, Lord Reith, Sir Archibald Forbes, Mr. R. P. Morrison, and Viscount Ednam.

Change of Name and Address

The Hanwell Engineering Co., Ltd., of Countess Road, Northampton, has been taken over by Pollard Bearings Ltd., and the title has been changed to Pollard Bearings (Northampton) Ltd. The telephone number remains Northampton 3766/7/8.

Igranic Limited have moved to 4 Albert Square, Manchester (tel. Blackfriars 8033).

The Newcastle and Nottingham offices of Dewhurst and Partners Ltd. are now 46 Great North Road, Newcastle-upon-Tyne 2 (tel. 22340) and Bentinck Buildings, Wheeler Gate, Nottingham (tel. 40214), respectively.

CORRIGENDUM

In the paper on "Tonnage Oxygen" by F. J. Clark and J. L. Harrison, which appeared in the July, 1957, issue of the *Journal* (vol. 186, pp. 305–323), the following errors have been noted on p. 323:

1. The price of caustic soda is quoted as £2 per ton; this should be £2 per cwt.

2. In Fig. 9 the cost of production should be in pence per 1000 ft³ and not per 10,000 ft³.

DIARY

3rd Oct.—Leeds Metallurgical Society—"Quantity Production of Grey Iron Castings," by P. A. Green—Chemistry Wing, The University, Leeds, 7.15 p.m.

4th Oct.—North East Metallurgical Society—Social evening—Teesdale Hall, Thornaby-on-Tees.

7th Oct.—East Midlands Metallurgical Society—Presidential Address, by N. S. Angus—Nottingham and District Technical College, Shakespeare Street, Nottingham, 7.30 p.m.

7th–14 Oct.—British Scientific Instrument Research Association—Open Days—Chislehurst.

7th–12th Oct.—Société française de Métallurgie—Journées Métallurgiques d'Automne—Paris.

12th Oct.—Institute of Welding—Conference on "Safety and Health in Welding"—54 Princes Gate, London, S.W.7.

12th Oct.—Swansea and District Metallurgical Society—Presidential Address, by J. S. Caswell—Central Library, Swansea, 6.30 p.m.

15th–17th Oct.—National Anti-Corrosion Week—Convention and Exhibition—Westminster.

17th–19th Oct.—Workmen's Safety and Factory Hygiene Congress and Exhibition—Düsseldorf.

23rd–25th Oct.—Verein Deutscher Eisenhüttenleute—Annual Meeting—Düsseldorf.

25th Oct.—North-East Metallurgical Society—"Metals used in the Jewellery and Silverware Industry," by Miss Dorothy Pile—Cleveland Scientific and Technical Institution, Corporation Road, Middlesbrough, 7.15 p.m.

28th–30th Oct.—Institution of Production Engineers—Convention on Materials Handling—Leamington Spa.

2nd–8th Nov.—Second World Metallurgical Congress—Chicago, Ill., U.S.A.

CO-OPERATIVE TRANSLATION SERVICE

The following translations are now available, in addition to those given on p. 55 of the September, 1957, issue of the *Journal*:

536. Shchukin: "Investigation of Stresses on Units of the Continuous Casting Installations for Steel." *Stal*, 1957, No. 4, pp. 320–321. (£1 6*s*. 0*d*.)

537. Ed. Bardin: "The Use of Oxygen in Steelmaking." 1955, Moscow. (Report by R. Sewell). (£2 0*s*. 0*d*.)

538. Borodin *et al.*: "Change-over of O.H. Furnaces from Oil to Natural Gas Firing." *Stal*, 1957, No. 2, pp. 124–129. (£2 10*s*. 0*d*.)

539. Kazarnovskii *et al.*: "Properties of O.H. Steel Processed with Oxygen." *Stal*, 1957, No. 2, pp. 152–157. (£2 0*s*. 0*d*.)

542. Berns: "Design and Performance of Hydraulic Descaling Plants." *Stahl u. Eisen*, 1957, vol. 77, No. 9, pp. 567–576. (£5 0*s*. 0*d*.)

543. Dehne: "Removing Dust from Brown Converter Waste Gases." *Stahl u. Eisen*, 1957, No. 9, pp. 553–562. (£4 10*s*. 0*d*.)

544. Eisenhuth: "Mechanical Descaling, particularly Bend Descaling, in Wire Production." *Stahl u. Eisen*, 1957, vol. 77, No. 6, pp. 324–334. (£6 5*s*. 0*d*.)

546. Tsirlin: "Modernization of Units of Slabbing Mill Equipment." *Stal*, 1957, No. 3, pp. 232–238. (£3 0*s*. 0*d*.)

572. Hofmaier: "Continuously Cast Products for Rolling Mill and Forge." *Stahl u. Eisen*, 1957, Jan. 24th, pp. 69–78. (£5 10*s*. 0*d*.)

574. Hempel: "Behaviour of Heat-resisting Steel in Long-period Tests at 500–700° C. Part VII." *Arch. Eisenhüttenwesen*, 1957, vol. 28, May June. (£2 5*s*. 0*d*.)

575. Born: "Influence of Sulphur in Furnace Atmosphere on Forming Behaviour of Unalloyed Steels." *Stahl u. Eisen*, 1956, vol. 76, June 28th, pp. 789–799. (£5 10*s*. 0*d*.)

584. Zur: "Economic and Technical Results of Operation of Waste-heat Boilers and High-temperature Cooling Plants installed on O.H. Furnaces." *Stahl u. Eisen*, 1957, Jan. 24th, pp. 95–100. (£2 15*s*. 0*d*.)

585. Elgh *et al.*: "Tests to Determine Carbon and Sulphur in a Combustion Furnace with H.F. Heating." *Jernkontorets Ann.*, 1956, vol. 140, No. 5, pp. 373–385. (£2 5*s*. 0*d*.)

591. Hamm and Kehrmann: "High-strength Bolts in Steel Construction." *Industrie-Anzeiger*, 1956, Dec. 18th. (£2 0*s*. 0*d*.)

592. Hamm and Kehrmann: "Design and Evaluation of High-strength Bolted Steel Joints." *Industrie-Anzeiger*, 1957, Jan. 15th. (£1 10*s*. 0*d*.)

607. Kononov: "Semi-continuous Casting of Stainless Steel." Russian Conference of 300 Continuous Casters in Odessa, Oct. 1955. (pp. 100–110). (£2 10*s*. 0*d*.)

608. Saveiko: "Mechanism of Hot Tearing of Steel Castings." Russian Conference of 300 Continuous Casters in Odessa, Oct. 1955. (pp. 241–251). (£3 0*s*. 0*d*.)

609. Gruzin: "Pouring Temperature and Hot Tearing." Russian Conference of 300 Continuous Casters in Odessa, Oct. 1955. (pp. 252–260). (£2 10*s*. 0*d*.)

610. Trubitsyn: "New Methods for Determination of Linear Contractions, Stress, and Resistance of Alloys to Hot Tears." Russian Conference of 300 Continuous Casters in Odessa, Oct. 1955 (pp. 261–266). (£1 15*s*. 0*d*.)

624. Beda *et al.*: "Rolling of Rails through Knifing Passes of Cogging Rolls." *Stal*, 1957, May, pp. 431–435. (£1 15*s*. 0*d*.)

625. Karpunin: "Rationalization of Rail Pass Design." *Stal*, 1957, June, pp. 536–540. (£2 0*s*. 0*d*.)

634. Trubin: "Advantages of Tilting as Compared with Fixed Furnaces." *Stal*, 1956, No. 9, pp. 780–782. (£2 0*s*. 0*d*.)

635. Lenorsky *et al.*: "Comparison between Tilting and Fixed Furnaces." *Stal*, 1957, No. 5, pp. 411–413. (£2 10*s*. 0*d*.)

636. Hansen: "Detonation and Shock Wave" (Report 301 of the Blast-furnace Committee of V.D.E.). *Stahl u. Eisen*, 1957, vol. 77, June 13th, pp. 803–813. (£5 0*s*. 0*d*.)

637. Kosmider and Schenck: "Dephosphorization of Basic Converter Steel to Very Low Contents of Phosphorus." *Stahl u. Eisen*, 1957, vol. 77, July 11th, pp. 917–926. (£5 0*s*. 0*d*.)

639. Reimann: "Automation in the Cold Rolling Mill." *Stahl u. Eisen*, 1956, vol. 76, Dec. 13th, pp. 1665–1668. (£2 0*s*. 0*d*.)

640. Adaryukov: "A Soviet Delegate's Observations on British Blast-furnace Plants." *Metallurg*, 1957, No. 3, pp. 45–48. (£2 0*s*. 0*d*.)

641. Schmale: "Automation of a 12-roll Reversing Cold Rolling Mill." *Stahl u. Eisen*, 1956, vol. 76, Dec. 13th, pp. 1698–1700. (£1 5*s*. 0*d*.)

653. Rylov: "Prospects for use of Calculating Machines for Automatic Control of Blast-furnace Running." *Stal*, 1957, No. 6, pp. 488–493. (£2 10*s*. 0*d*.)

657. Wepner: "Simultaneous Determination of Low-carbon and Nitrogen contents in Alpha-iron by Damping Measurement." *Arch. Eisenhüttenwesen*, 1956, July, pp. 449–452. (£2 15*s*. 0*d*.)

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ABSTRACTS OF CURRENT LITERATURE AND BOOK NOTICES

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MINERAL RESOURCES

Important Low Grade Iron Deposits. In the Province of Quebec. R. Bergeron. (*Canad. Min. J.*, 1957, **78**, Apr., 105–108). A review of deposits and present developments in concentration.

Woodstock Manganese Ores. Occurrence and Treatment. G. C. Monture. (*Canad. Min. J.*, 1957, **78**, Apr., 117–120).

ORES—MINING AND TREATMENT

Iron-Ore Mining in Lapland. (*Iron Coal Trades Rev.*, 1957, **174**, Mar. 29, 723–730). Details are given of the reconstruction scheme of the LKAB Mining Co., operating Sweden's Arctic iron-ore mines at Kiruna and Gällivare (Malmberget). The new equipment to be installed to meet the increase in output is described, and the mining methods to be used are outlined.

Studies on Vanadium and Titanium Bearing Iron Ore of Mayurbharj. R. K. Mitra and G. P. Chatterjee. (*Trans. Indian Inst. Met.*, 1955–56, **9**, 111–121). The different mineral constituents, and their mode of occurrence with particular reference to V have been studied.—D. H.

A Practical Solution to a Fuel and Lubrication Problem. C. R. Burton. (*Yearly Proc. Assoc. Iron Steel Eng.*, 1956, 757–761). Maintenance of ore mining equipment is discussed.

British Railways Iron Ore Wagons. Hopper Type Design of 730 cu. ft. Capacity to Further Increase in Steel Production in Scotland. (*Rail. Gaz.*, 1957, **106**, May 10, 535–536).

Transporter with Sliding and Skewing Girder Rationalizes Ore Handling Even Where Space Conditions are Unfavourable. K. Schmoll. (*Demag News*, 1956, (143), 9–12). The unloading plant at Niederrheinische Hütte, Duisburg, is described.

New Ore Handling, Screening and Sintering Plant. (*Australasian Eng.*, 1957, **49**, Mar. 7, 42–43). A brief illustrated account of the Port Kembla plant.

The Transformation of Haematite (α-Fe_2O_3) into Ferromagnetic Iron Oxide (γ-Fe_2O_3). F. J. Lecznar. (*Acta Techn.*, 1957, **16**, (3–4), 383–398). Roasting in oxidizing or reducing atmospheres is investigated.

Sintering: Race to Hold Costs Down. (*Steel*, 1957, **140**, Jan. 28, 98–100). Sintering capacity in U.S.A. and Canada will be doubled by 1959. The new plants are listed and the critical role of beneficiation in future iron production is discussed. The effect of increasing SiO_2 content of ores is also considered.—G. F.

Roasting Reaction of Ferrous Sulfide. K. Niwa, T. Wada, and Y. Shiraishi. (*Trans. Amer. Inst. Min. Met. Eng.*, 1957, **209**; *J. Met.*, 1957, **9**, Feb., 269–273). Using a spring-balance and X-ray diffraction analysis, the authors have studied the rate and mechanism of oxidation of FeS in the range 500–700° C. Complete oxidation begins at 600° C, accompanied initially by a slight weight increase which is interpreted in terms of iron ion migration. Above 600° C the rate of oxidation does not change with temperature, the rate-determining factor being diffusion of gas.—G. F.

FUEL—PREPARATION, PROPERTIES, AND USES

Raw Material Inventory of Coal. W. S. Massa. (*Yearly Proc. Iron Steel Eng.*, 1956, 1063–1065). Photogrammetric stock pile inventory methods are discussed.

Developments in Coal Preparation Practice. A. E. Green. (*Trans. Inst. Min. Eng.*, 1957, **116**, May, 617–632). A review of cleaning methods, with discussion.

Flotation. (Unit Operations Review). I. Hoffman and N. Arbiter. (*Indust. Eng. Chem.*, 1957, **49**, Mar., Part II, 493–496). (95 references).

The Size of Solid Fuel in Relation to the Behaviour of Combustion and Gasification Appliances. J. R. Arthur and W. D. Smith. (*Brit. Coal Utilisation Res. Assoc. Monthly Bull.*, 1956, **20**, Nov., 429–444). A section on metallurgical furnaces is included.

What Do We Know About Coke? D. E. Krause. (*Mod. Castings*, 1955, **28**, Dec., 55–56). A discussion of an index for coke performance in the cupola with an account of cupola tests and stack gas analyses.

Chemicals From The Steel Plant. (*Steel*, 1957, **140**, May 13, 128, 130, 132). A review of coking products (benzene, toluene, etc.) and pickle liquor regeneration, notably by the Zahn process.

Pressure Gasification of Brown Coal at Morwell, Australia. R. S. Andrews. (*Gas World*, 1957, **145**, May 18, 1048–1057).

The Determination and Significance of the Width of the Plastic Layer in Coal. J. Nadziakiewicz. (*Coke Gas*, 1957, **19**, May, 193–198). Methods of testing are given. It is concluded that the maximum width of a coal heated under standard conditions is a characteristic feature related to caking index, degree of maximum fluidity etc. and depends also on conditions of formation and on rate of heating.

Determination of Volatile Matter in Coke. A. R. Myhill. (*Coke Gas*, 1957, **19**, May, 204–207, 213). The measurement is used to assess degree of combustibility and completeness of carbonization. Methods are reviewed and discussed.

Balanced Pressure Coke Gas Distribution. H. V. Flagg. (*Yearly Proc. Assoc. Iron Steel Eng.*, 1956, 324–332). An account of the use made at Armco of surplus gas from the Hamilton and Middletown plants. Delivery through 10 miles of 16-in. main at 5–9 $\times$ 10^5 ft^3/hr is described.

Persistence of Phenol in Water. R. D. Hoak. (*Mellon Institute of Industrial Research. Progress Report of Amer. Iron Steel Inst. Fellowship No.* 278–19, 1957, Jan., 463–470; Feb., 488–496). Tests on addition of phenolic impurities to streams and their persistence with methods of analysis are briefly recorded.

AIR POLLUTION AND SMOKE

Air Pollution. K. Kay. (*Anal. Chem.*, 1957, **29**, Apr., Part II, 589–604). A review of analytical aspects is given covering 1952–1956. (498 references).

Clean Air Conference: Impact of New Legislation on the Iron and Steel Industry. J. M. Beskine. (*Iron Steel*, 1957, **30**, Apr., 143–146). A report is given of a conference concerned with implementation of the new and extended clean air legislation. The subjects discussed included the technical and economic aspects involved, dust problems in the iron and steel industry, foundry dust emissions, and mechanical and electrostatic cleaners.—G. F.

Dust Problems of the Iron and Steel Industry: Measures to Stop Atmospheric Pollution. M. W. Thring and R. J. Sarjant. (*Iron Coal Trades Rev.*, 1957, **174**, Mar. 29, 731–735). The Clean Air Act necessitates further attention to the cleaning of waste gases. The authors discuss the problems involved in connection with O.H. furnaces, Bessemer converters, arc furnaces, cupola iron melting furnaces, blast furnaces, coke ovens, reheating furnaces, and small heat-treatment furnaces.

The Foundry's Attack on Air Pollution. (*Mod. Castings*, 1956, **30**, Sept., 39–48). A general review of the problem and its solutions is presented.

TEMPERATURE MEASUREMENT AND CONTROL

The Industrial Measurement of Gas Temperature. A. M. Godridge, R. Jackson, and G. G. Thurlow. (*Trans. Soc. Instrument Techn.*, 1956, **8**, Sept., 103–132). Limitations of the sheathed thermocouple and similar devices are discussed and suction pyrometers, the total heat meter and pneumatic pyrometers are described. Practical performances of these devices are then outlined at various ranges up to or above 1400° C. The suction pyrometer and venturi pneumatic pyrometer are then reviewed in some detail, with an appendix on theory. (Discussion and written reply).

The Venturi Pneumatic Pyrometer. G. G. Thurlow. (*Coke Gas*, 1957, **19**, May, 201–203). The BCURA instrument for local gas temperatures is described.

REFRACTORY MATERIALS

Some Technological Implications of Fundamental Research. W. F. Ford. (*Refract. J.*, 1957, **33**, Feb., 76–80). An address on developments in refractories with a review of recent advances.

The Properties of MgO Powders Prepared by the Decomposition of $Mg(OH)_2$. D. T. Livey, B. M. Wanklyn, M. Hewitt, and P. Murray. (*Trans. Brit. Ceram. Soc.*, 1957, **56**, May, 217–236). Various temperatures in air and *in vacuo* were used and density, surface area, and heat of solution determined. Sintering phenomena are discussed.

Structural Interpretation of Immiscibility in Oxide Systems: I. Analysis and Calculation of Immiscibility. E. M. Levin and S. Block. (*J. Amer. Ceram. Soc.*, 1957, **40**, Mar., 95–106). Glass systems are mainly considered, but methods of study are reviewed. Binary and ternary silicate systems are discussed. **II. Coordination Principles Applied to Immiscibility.** (Apr., 113–118). Ionic radii theory is applied, mainly to glass systems.

Facts of Refractory Life. L. R. Jenkins and C. C. Lawson. (*Mod. Castings*, 1956, **29**, May, 123–124). Furnace bottom refractories are compared.

Pyrophyllite: A New Raw Material for Ceramists. M. L. Misra, R. P. Saxena, and V. G. Upadhyaya. (*Ceramic Digest*, 1957, **1**, May, 450–454). A review including uses in refractories. (27 references).

Basic Refractories: Variation with Temperature of Modulus of Elasticity. W. R. Davis and G. R. Rigby. (*Trans. Brit. Ceram. Soc.*, 1957, **56**, May, 259–276). Chrome-magnesite, magnesite-chrome, magnesite and chrome bricks were examined at temperatures up to 1200° and also after reheating 14 times. The sonic method was used with longitudinal vibrations.

Some Problems Connected with Magnesite–Dolomite Refractories. F. Nadachowski. (*Refract. J.*, 1956, **32**, Sept., 436–442, 444). Phase calculations on oxide components and their significance are discussed. Reactions during firing are considered and a batch composition formula is given. Finally dicalcium silicate is reviewed.

Results of Laboratory Tests of High Duty and Super Duty Fire-Clay Plastic Refractories. R. A. Heindl and W. L. Pendergast. (*Amer. Ceram. Soc. Bull.*, 1957, **36**, Jan., 6–13). 24 Brands were examined for water content, particle size distribution, workability index, bulk density, wet strength, pyrometric core equivalent, and ignition loss. Resistance to thermal shock was measured and shrinkage, nodulus of rupture and Young's modulus after preheating at various temperatures.

Some Notes on the First Use of Silica as a Refractory. (*Refract. J.*, 1956, **32**, Nov., 534–537). Dinas bricks are discussed.

A Comparative Study of Indian and Foreign Silica Bricks. H. V. B. Rao and Rabindar Singh. (*J. Sci. Ind. Res.*, 1957, **16A**, Apr., 183–188).

Duricrust Silica for High-Quality Refractory Bricks Near Oodnadatta. R. I. Chugg. (*South Australia Mining Review*, 1956, No. 101, 65–71).

Eliminating Refractory Dust. (*Refract. J.*, 1956, **32**, Dec., 594–597). Treatment of silica bricks with binders is reviewed.

Spalling Tests on Blast Furnace Brick. K. A. Baab. (*Amer. Ceram. Soc. Bull.*, 1957, **36**, Jan., 14–17). In tests on a simulated furnace wall it was determined that the presence of moisture has no detrimental effect on degree of spalling if heated at 70–100° F/hr so that drying of the furnace before blowing-in has been over-emphasized. A blast furnace may require weep holes in the hearth jacket for the escape of water. The ASTM spalling test without preheat and with controlled heating evaluates relative spalling characteristics of bricks. Other standard tests should be developed for initial heating and for maximum heating rates.

Co-operative Research on the Study of Casting Pit Refractories. L. Ferro and A. Recchi. (*Met. Ital.*, 1957, **49**, Apr., 242–252). [In Italian]. The authors make a detailed study of the mechanical, chemical, physico-chemical and mineralogical characteristics of casting pit refractories. Numerous tables are given setting out the specification of various refractories tested and photomicrographs are given of these samples.

Bond Strength, Radioactive Tracers, and Casting Pit Refractories. D. H. Houseman. (*Refract. J.*, 1957, **33**, May, 192–195, 206). The W. J. Rees Fellowship Report. **The Influence of Temperature on the Physical and Mechanical Properties of Compacted Refractory Materials.** (192–194). **Diffusion in Oxide Systems at High Temperatures.** (194–195). **Casting Pit Refractories as a Source of Non-Metallic Inclusions in Steel.** (195, 206). Only brief outlines are given.

Ladle Bricks for Electric Steel Manufacture. III. Consideration of Some Laboratory Tests. U. Ozawa and S. Tokoro. (*Rept. Government Industrial Research Inst. Nagoya*, 1956, **5**, Feb., 93–99; English summary, 10–11). Failures of aluminosilicate bricks by erosion, corrosion, and spalling are discussed and testing methods compared.

The Interactions of Molten Metals and Refractory Materials. D. H. Houseman. (*University of Cambridge, Abstracts of Dissertations*, 1954–1955, 190–191). Penetration pressure studies are reported using clay bonded sand mixes and zircon compacts.

IRON AND STEEL, GENERAL

Some Notes on Iron and Steel Production in Sweden. J. Dunning. (*Metallurgie*, 1957, **55**, Mar., 131–132). A short review of the Swedish steel industry and in particular of comparison with iron and steel production in the United Kingdom is presented.—B. G. B.

Iron and Steel Works at Workington. (*Engineer*, 1957, **203**, May 24, 804–805). An account of reconstruction at the Workington Iron and Steel Co. works is given.

Detroit at Portsmouth. T. J. Ess. (*Iron Steel Eng.*, 1957, **34**, D.1–D.20). A detailed description is given of the Detroit Steel Corp. plant at Portsmouth. The paper covers iron ore preparation, coke ovens, blast furnaces, steel plant and rolling mills.—M. D. J. B.

DEMAG's Share in the Reconstruction and Development of Europe's Steelworks. H. Hofmeister and C. Herrmann. (*Demag News*, 1956, (143), 13–23). An illustrated account of plant installed in Europe with discussion of development work.

Recent Trends in Ferrous Metallurgy. M. Szele. (*Kohászati Lapok*, 1956, **11**, (7), 297–300). The author refers to recent trends in ferrous metallurgy such as: preparation of coal cake before charging in the coke oven, production of ore–coke mixtures, various ore concentration-, ore dressing- and ore roasting methods, the Lonley process, the pelletizing and blooming hearth processes, high pressure blowing, moisture control of air for blowing, the low-shaft furnace, the Lubatti method, the use of O_2 in steel making processes, the turbo-hearth process, various continuous casting methods for steel, vacuum casting, continuous rolling mills, automatic roll setting and continuous cold sheet rolling.—P. K.

Research and the Future of Iron and Steel Making. (Sir) C. Goodeve. (*Australasian Eng.*, 1957, **49**, Mar. 7, 59–60). An address at the opening of the B.H.P. Central Research Laboratories, N.S.W.

BLAST-FURNACE PRACTICE AND PRODUCTION OF PIG IRON

Design and Operation of a Blast Furnace with a Carbon Bosh Lining. E. K. Miller, jun. (*Iron Steel Eng.*, 1957, **34**, April, 91–94). The author discusses the advantages of carbon bosh lining to blast furnaces. Reference is made to the No. 10 furnace at Gary and to the work of Chesters and Elliott. The author claims smoother furnace operation, the elimination of cooler trouble, a larger working volume and a saving in fuel.—M. D. J. B.

Blast Furnaces in Czechoslovakia: Construction of Thin-Walled Furnaces. (*Iron Coal Trades Rev.*, 1957, **179**, Mar. 29, 740–743). About half the blast furnaces operating in Czechoslovakia are of thin-walled construction, with lining thickness of 6–10 in. Details of operating experiences are given, showing that the furnaces are suitable for smelting various grades of ore. In long-term reconstruction plans, most of the furnaces in the country are to be replaced by thin-walled units.—G. F.

Ironmaking in Japan. K. Wada. (*Iron Steel Eng.*, 1957, **34**, March, 107–109). The article describes increases of productivity of blast furnaces in Japan, reductions in coke consumption and improvements in equipment, and gives various production and consumption statistics.—M. D. J. B.

Possibilities of Desulphurizing Blast-Furnace Hot Metal. I. By Additions of Aluminium Near the Iron Notch During Casting. A. Banerjee, V. G. Paranjpe, and S. Visvanathan. **II. By Injecting Fluidized Agents.** P. K. Chakravarty, V. G. Paranjpe, and S. Visvanathan. (*Tisco*, 1957, **4**, Apr., 74–79; 80–88). Claims for the Al process were not fulfilled and the main reason appeared to be high Si and Ti in the pig iron used. Fluidized CaC_2, cyanamide, silicide, lime, $CaCO_3$, CaF_2, and soda were used. Low-grade lime is improved by adding CaF_2, C, Fe–Mn, calcium silicide and Al. Powdered slags were also used and correlated with composition and fluidity.

Distribution of Titanium Between Blast-Furnace Metal and Slag. P. Mehta and V. G. Paranjpe. (*Tisco*, 1957, **4**, Apr., 95–99). Relationships between temperature and Ti reduction, Ti reduction, and Si reduction, and Ti and Si reductions and Mn reduction are discussed.

Control of Furnace Gas Components. I. Detecting Device. T. Sato and M. Aoki. (*Rep. Government Industrial Research Inst. Nagoya*, 1956, **5**, Feb., 81–85; English summary, 9–10). An infra-red gas analyzer of negative filter type for continuous CO recording is described.

Automatic Control of Wet Gas Cleaning for Blast Furnace Plant. R. Porlezza and M. Valussi. (*Met. Ital.*, 1957, **49**, Apr., 290–294). [In Italian]. The control equipment described operates hydraulically and distributes the load uniformly between the 4 Dingler gas blowers. At the same time the equipment controls gas pressure down-stream of the dust catchers and also up-stream of the compressors so that any variations in pressure due to B.F. operation can be compensated for.—M. D. J. B.

Future of Low Shaft Furnaces in India. M. N. Dastur and R. D. Lalkaka. (*Trans. Indian Inst. Met.*, 1955–56, **9**, 59–82). The operating features of two representative types of low shaft furnace processes for the production of iron from inferior raw materials—the Calbe and D.H.N. types—are described. Capital and operating costs for future hypothetical low-shaft furnace installations are briefly discussed.—D. H.

PROPERTIES, TREATMENT AND USE OF SLAGS

Thermodynamics of Liquid Blast-Furnace-Type Slags. I. Evaluation of Activities of CaO and SiO_2. Chou Yuan-Hsi. (*Acta Metallurgica Sinica*, 1956, **1**, (2), 127–141). [With English summary]. Calculations for $CaO–SiO_2$, $CaO–SiO_2–Al_2O_3$, and $CaO–MgO–SiO_2–Al_2O_3$ systems are carried out from existing data and from plots of these activities a new expression for basicity is proposed. Al_2O_3 shows amphoteric behaviour in the new expression. **II. The Application of a New Basicity Ratio to Desulphurization of a Carbon-saturated Iron.** (143–154). Existing data are used to correlate basicity ratio with desulphurizing power by evaluating the activity of CaS and calculating a sulphur distribution curve. This is in good agreement with observed values.

Methods for Reclaiming and Processing Scrap from Steel Plant Slags and Refuse. L. J. Fritz. (*Iron Steel Eng.*, 1957, **34**, April, 95–97). This article describes a magnetic separator capable of handling 200 cu. yards of slag per hour. It is claimed that for a works producing 2·5 million ingot tons a year up to 50,000 tons of metallics can be recovered.

Mathematical Treatment of Multicomponent Systems. D. L. Heath. (*J. Amer. Ceram. Soc.*, 1957, **40**, Feb., 50–53). A general equation for any number of components is given and the $Na_2O–Fe_2O_3–Al_2O_3–SiO_2–CaO$ system is treated as an example.

WROUGHT IRON

Wrought Iron Craze Gains Metal Bigger Piece of Furniture Pie. (*Western Metals*, 1957, **15**, Feb., 63). A note on the work of two Pasadena firms.

DIRECT PROCESSES

Direct Reduction of Iron Ore to Yield Usable Steel. J. Mohan, P. K. Gupte, and B. R. Nijhawan. (*Trans. Indian Inst. Met.*, 1955–56, **9**, 247–262). A process is described for producing steel direct from Indian iron ore for use on a cottage industry basis. Crushed ore is packed in a paper tube and embedded in solid charcoal in a steel canister, which is heated to 900° C for reduction and then to 1100° C for sintering. A fairly compact steel bar of density 4–7 results which is amenable to hot working and heat treatment. Some potential applications of this process are discussed.—D. H.

Stora's Kal-do Rotary Oxygen Steelmaking Process. B. Kalling and F. Johansson. (*Blast Furn. Steel Plant*, 1957, **45**, Feb., 200–203). A description is given of a new steelmaking process developed at the Domnarvet works of Stora Kopparbergs Bergslags A/B, Sweden, in which oxygen is introduced into a rapidly rotating furnace. Results obtained are given and indicate that the technique is of considerable importance and very flexible in operation.—B. G. B.

Steel Refining with Oxygen in a Rotating Furnace According to the Kaldo Process. B. Kalling and F. Johansson. (*Jernkontorets Ann.*, 1957, **141**, (4), 189–205). A detailed description of the process is given and of a 30-t furnace now operating.

PRODUCTION OF STEEL

The Shape of Steel in Canada. (*Canad. Metals*, 1956, **19**, Dec., 8). A short review of modern advances in the Canadian steel industry is presented. Brief mention is made of direct reduction and continuous casting.—B. G. B.

Atlantic Steel Company Makes Plant Improvements. C. Longenecker. (*Blast Furn. Steel Plant*, 1957, **45**, Feb., 174–192). In 1951 the output of steel was increased by the installation of a 75-ton electric furnace and in 1955 a second furnace

was added. A modern rod and bar mill went into production in late 1956. A description of the plant and operating characteristics is given.—B. G. B.

Transportation Control in Steelmaking. J. L. Kerins. (*Iron Steel Eng.*, 1957, **34**, March, 134–137). The problems involved in the transport of materials are discussed. Methods of costing are briefly described and methods of control touched on.

Kinetic Behaviour During the Reduction of Metallic Oxides. T. Rosenquist. (*Tidsskr. Kjemi, Bergvesen Met.*, **17**, 1957, (1), 1–6). [In Norwegian]. The author considers reduction speeds as functions of various factors such as gas content, time, temperature, condition of the material with particular reference to Fe_3O_4 and Fe_2O_3. Graphs, tables, and photomicrographs relating to his experiments appear in the text. (17 refs.).—F. R. H.

Mixing of Steels During the Hot Working Processes. J. Lántzky. (*Kohászati Lapok*, 1954, Oct., 440–444). After referring to the drastic consequences of the mixing of steels the author discusses the causes of this and comments on the mode of its elimination. Finally he describes the various methods of the sorting of mixed steels e.g. chemical analysis, especially of carbon content, hardness testing, sulphur printing, the magnetic sorting bridge, and grinding spark observation.—P. K.

The Need for Less Sulphur in Deoxidised Steel. H. W. McQuaid and N. P. Goss. (*Metal Progress*, 1957, **71**, Mar., 65–71). The detrimental influence of sulphur in quality steels is discussed. More than 0·02% S in Al-killed, fine-grained steel produces undesirable ferrite in the martensitic microstructure. It is considered that a maximum content of 0·02% S will become standard for quality steels in the U.S.A.—B. G. B.

Evaluation of Activities in the Liquid Systems Ag–Pb, Ag–Al and Fe–Al and Application of the Result to Deoxidation of Steel. Chou Yuan-Hsi and J. F. Elliott. (*Acta Chimica Sinica*, 1956, **22**, (1), 14–23). A calculation of the activity coefficient of Al in Ag and hence, from Chipman's data, in Fe. The deoxidation constant is then calculated and compared with the experimental value.

Use of Oxygen for Pretreatment of Molten Iron. Small-Scale Experiments under Acid and Basic Conditions. J. A. Charles and T. C. Churcher. (*Iron Coal Trades Rev.*, 1957, **174**, Mar. 22, 667–672). Silicon removal by oxygen lance or jet is investigated, and removal of phosphorus is also considered.

Metallurgical Analysis as a Tool for Maintenance and Operating Departments. R. H. Davis, J. V. Russell, and M. E. Olson. (*Iron Steel Eng.*, 1957, **34**, April, 139–148). A symposium of three papers dealing with the organization of steel plant maintenance, the analysis of failures in works operation and the uses of metallurgical analysis as a tool for tracking down faulty pieces of equipment.—M. D. J. B.

Oxygen in Steelmaking. J. Mackenzie. (*Technology*, 1957, **1**, June, 136). A brief account of oxygen lancing and of the L–D, Kalling and Rotor processes.

Oxygen in Steelmaking. (*Mech. World*, 1957, **137**, Jan., 28–30). A review of O.H., converter and arc furnace practice with accounts of refining processes, silicon removal, and flame enrichment.

Use of Oxygen at Abbey Melting Shop, Steel Co. of Wales Ltd. A. J. Kesterton. (*Trans. Amer. Inst. Min. Met. Eng.*, 1957, **209**; *J. Met.*, 1957, **9**, Feb., 274–280). The author describes the system of oxygen-lancing the O.H. bath at Abbey Works of Steel Co. of Wales Ltd., where a water-cooled probe is introduced through the roof. Operating data are given and the effect on carbon removal is discussed. A system of slag control for sulphur removal, involving control of oxygen and lime additions and bath carbon, is described.

A New Look at the Nature of the Open-Hearth Process. B. M. Larsen. (*Amer. Inst. Min. Met. Eng. Special Report No.* 1, pp. 47). A unified analysis of the O.H. process is developed in relation to factors controlling speed and fuel efficiency. The analysis indicates that fuel consumption might be reduced to about 10^6 BTU/t, with a charge-to-tap time of 5 h, with certain precautions. Flow of heat into the bath, O_2 diffusion and C oxidation, the problem of supply of excess preheated air and air oxidation and net heat requirements are the section headings. (20 references).

The Climate of the Open-Hearth Furnace. J. H. Chesters. (*Iron Steel*, 1957, **30**, Mar., 87–93; Apr., 125–129). In discussing the " climate " of the O.H. furnace, the author first deals with temperature, and considers its general level, fluctuations, and distribution throughout the furnace. He then describes " wind velocity and direction," discussing and illustrating the flow pattern of the gases in the furnace. Next he considers the flux content of the gases and its effect on refractory wear, and describes the alumina probe method of measuring the deposition. A first approximation to predict the rate of wear, assuming equilibrium conditions, is made.—G. F.

Open Hearths Grow Bigger. (*Steel*, 1957, **140**, Apr. 22, 86, 88). An account of Weirton Steel Co.'s 600-t O.H. with plan and description is given.

Systematic Relining of Open Hearth Furnace Doors at Gary Steel Works. (*Indust. Heating*, 1957, **24**, Apr., 787, 788, 790, 792, 794, 796). A 35% increase of heat for 50 furnaces in 4 shops is claimed after installation of a central station for door relining.

Central Relining Station Boosts Openhearth Door Life. (*Iron Age*, 1957, **179**, Mar. 7, 130–131). The Gary works of U.S. Steel Corp. has a large central relining station which handles all doors from the four melting shops, totalling more than 50 furnaces. The work sequence is described and the advantages gained by central maintenance are discussed.—G. F

Similarity Criteria for Dust Deposition Tests in Models. R. A. Granville, A. Sigalla, and Hope Lubanska. (*J. Iron Steel Inst.*, 1957, **187**, Oct., 121–125). [This issue.]

Unique Procedure Helps Geneva Speed Increase in Steel Capacity. (*Iron Steel Eng.*, 1957, **34**, March, 138–141). Prefabrication of O.H. furnace parts has contributed to much reduced downtime at the Geneva Works. The article describes a complete O.H. furnace built outside the melting shop, transported by rail to the site and moved into position ready for firing.—M. D. J. B.

Safety Geared to New Shop Tempo. R. G. Phelps. (*Steel*, 1957, **140**, May 6, 92, 95). A new O.H. shop is described from the safety aspect.

Electric Furnace Steel Conference. E. C. Wright. (*Metal Progress*, 1957, **71**, Mar., 93–96). A short summary of the 13th Electric Steel Conference held in Chicago in December 1956 is presented. The high price of scrap was the primary concern and other sources of metal (sponge iron, hydrogen reduced iron, and desiliconized pig iron) were considered.

Economical Melting of Chromium Bearing Scraps by Means of Oxygen Blowing. E. Weigl. (*Kohászati Lapok*, 1954, **9**, Nov., 490–492). The blowing of 4–5 m^3 oxygen into the bath in an electric arc furnace for each ton of steel was necessary at adequate high melting temperature to obtain a 80–90% yield of the chrome content of steel scrap containing about 1% Cr.—P. K.

Sponge Iron in Electric Arc Furnaces. J. L. Stalhed. (*J. Met.*, 1957, **9**, Feb., 246–249). Sweden uses more sponge iron than any other country at the present time. The author describes Swedish experience and techniques in the use of sponge iron in electric arc furnaces for producing high-grade steel. The material gives a higher furnace yield, better rolling properties, and reduces tramp elements.—G. F.

Some Aspects of the Durability of the Roofs of Electric Arc Furnaces. I. Farkas. (*Kohászati Lapok*, 1956, **11**, (6), 248–253). Ignoring the present experimental rammed roof lining and referring to the unsuitable quality of silica bricks in Hungary the author suggests the use of chrome-magnesite bricks but in cross arch rather than in concentric construction.

The Production of Steel in Induction Furnaces. E. Lendvai. (*Kohászati Lapok*, 1954, **9**, Oct., 228–234; Nov., 252–261). After referring to the principles of induction steel melting the author reviews the various kinds of induction furnaces and crucibles. Later he discusses in detail steel making methods in acid and basic lined high-frequency furnaces.

An Exposition of Alloy Steels for the Engineer. J. S. Vatchagandhy. (*Tisco*, 1957, **4**, Apr., 63–73). A review with much tabulated data.

The Importance of Light Metals in Ferrous Alloys. L. Jeníček. (*Acta Techn.*, 1957, **16**, (1–2), 117–119). [In German]. A new alloy, Piroferal, containing 30% Al is described with its heat and corrosion resistances. Some notes on Mg in grey cast iron are added.

Know Stainless Steels When Selecting for Equipment. W. E. McFee. (*Indust. Eng. Chem.*, 1956, **48**, Nov., 1964–1970). Stainless steels are classified and their resistance to acids and susceptibility to corrosion cracking and other faults outlined.

Cast Alloy Resists Corrosion. (*Steel*, 1957, **140**, Jan. 28, 95).

A summary is given of the properties of CD–4MCu, a new high-strength cast alloy with corrosion resistance and mechanical properties comparable to 18–8 stainless steel. Developed by the Alloy Casting Institute, its composition is 25–27% Cr, 4¾–6% Ni, 1¾–2¼% Mo, 2¾–3¼% Cu, 0·04% C max., and 1% Mn max.—G. F.

Refractory Gun Repairs Hot Furnace. (*Steel*, 1956, **139**, Oct. 29, 130). The use and method of operation of a gun for repairing open-hearth refractories are described. A ton of refractory can be emplaced in a few minutes at any time in the furnace cycle. The ramming-mix or gun-refractory is mixed with water and blown out with compressed air.

Measurements of the Size of Droplets from Convergent–Divergent Nozzles used in Oil Burners for Steel Furnaces. E. J. Burton and J. R. Joyce. (*Inst. Fuel, Advance Copies*, 1957, Feb. 27, pp. 4). Two nozzles were examined at fuel flows of 70–300 lb/h with air : fuel ratios from 0·7 to 1·7 lb/lb by using a wax of the same viscosity and analysing the size distribution after solidification in flight. The median size ranged from 47–70 μ and neither nozzle profile nor distance of fuel pipe from nozzle entrance had any appreciable effect on distribution.

Developments in Open Hearth Operations. L. S. Moore. (*Blast Furn. Steel Plant*, 1957, **45**, Jan., 48–49). A short review of recent developments in furnace construction, refractories, use of oxygen, and charging methods is presented.

The Heating-up of Open Hearth Furnaces with Silica Brickwork. R. Schröter. (*Neue Hütte*, 1956, **1**, Sept., 458–468). It is essential for the rationalization of the heating-up process that the maximum admissible difference in temperature between neighbouring layers of bricks be calculated. At temperatures above 100° C the maximum permissible temperature variation can be calculated by dividing the thermal expansion coefficient of the layer having a higher temperature into the maximum tolerable expansion of the layer having a lower temperature.—L. J. L.

Heating up Silica-brick Lined Open-hearth Furnaces. II. The New Heating-up Process. R. Schröter. (*Neue Hütte*, 1956, **1**, Nov., 537–544). A new heating-up method is described that involves the use of novel measuring techniques. Temperatures in the brickwork are measured at varying distances from the internal furnace wall, so that changes in firing can be rapidly determined. Heating-up is so regulated that there is no discontinuity in the temperature gradient in the brickwork between 100 and 300° C.—L. J. L.

Study on Melting Practice of O.H. Furnace Steel Making. On the Oxidizing Power of the Lime Boil Reaction. A. Yoshida et al. (*Tetsu to Hagane*, 1956, **42**, Sept., 738–740). [In Japanese].—K. E. J.

Influence of Pig Ratio on Open Hearth Practice. J. Yamamoto et al. (*Tetsu to Hagane*, 1956, **42**, Sept., 747–749). [In Japanese]. Fuel consumption per ingot ton and melting time are at a minimum at a pig ratio of approx. 45%. Times for scrap charging, hot metal, melting, and refining are shown for pig ratios between 40 and 80%. Above 60%, higher pig ratios enable smelting times to be reduced and the oxygen used per ton to be increased.—K. E. J.

A Metallographic and Mineralogical Study of a Basic Open Hearth Heat. P. M. Power and J. C. Campbell. (*Canad. Min. Met. Bull.*, 1956, **49**, Nov., 793–802). Slag and metal samples were taken simultaneously from a low-carbon heat. The microconstituents were examined, and the change in structure from high-P white cast iron to steel. The slag structure is also described as seen on polished sections.

Study on the Melting and Refining Practice of Tilting O.H. Furnaces. III. On the Control of Decarburizing Rate and Oxygen Content. M. Nishiwaki et al. (*Tetsu to Hagane*, 1956, **42**, Sept., 744–746). [In Japanese]. The relationships between the carbon and oxygen contents in the three stages of the refining period are traced; and relationships are shown between the product [C][O] and decarburizing rate for three levels of carbon content. Relationships between decarburizing rate and excess oxygen content are shown for conditions of ore boiling, oxygen blowing, normal boiling, and just before tapping.—K. E. J.

Heat Transfer in the Open Hearth Furnace. M. W. Thring. (*Indust. Heating*, 1956, **32**, Sept., 1841–1850, 1856; Nov., 2384–2390). Flame length and emissivity calculations are presented from work by the International Flame Radiation Committee, and heat flow balances for steel heats given. A heat transfer model allows the calculation and the model is improved to give conditions nearer to those in the actual furnace.

Investigations of Flow Conditions in a Model of a Maerz-type Open-hearth Furnace. H. Stollberg and K.-F. Lüdemann. (*Neue Hütte*, 1956, **1**, Nov., 525–536). Flow in a 1 : 10 model of a 60-ton furnace was made visible by charcoal sparks and flour. Vortices in the intake slag chambers were found to determine flow conditions in the heating chamber. Flow from the two air shafts formed two horizontal contra-rotating vortices between bath surface and arch. Some backing of flow along the longitudinal axis of the hearth was found to occur.—L. J. L.

Oxygen during Refining Period in the Basic Open-Hearth Furnace. T. Fujii. (*Tetsu to Hagane*, 1956, **42**, Sept., 742–744). [In Japanese]. Thermodynamic relationships affecting the contents of carbon, FeO, and other metallic and non-metallic oxides are discussed.—K. E. J.

Oxidation of Phosphorus and Manganese During and After Flushing in the Basic Open Hearth. J. F. Elliott and F. W. Luerssen. (*J. Met.*, 1955, **7**, Oct., 1129–1136). Phosphorus and manganese appear to approach closely to equilibrium between metal and slag towards the end of flush and just after. The temperature difference between slag and bath may be as much as 450° F at this stage. The effect of composition on MnO activity in the slag is estimated.

Oxidation of Manganese Dissolved in Liquid Iron. B. V. Linchevskii and A. M. Samarin. (*Doklady Akad. Nauk S.S.S.R.*, 1956, **110**, (2), 209–211). [In Russian]. A determination was made of equilibrium relations between iron–manganese solutions and steam–hydrogen mixtures at 1565° and 1605° C, by means of a study of the formation of the oxide film on the surface of the metal. Curves showing the relation between the content of manganese and the oxidation potential of the gas phase and also between the content of manganese and the composition of the oxide, are given.

Study on the Oxidizing Power of Steelmaking Slags. I. Activity of FeO in Saturated FeO–SiO_2 and FeO–CaO Slags. S. Watanabe et al. (*Tetsu to Hagane*, 1956, **42**, Sept., 861–863). [In Japanese]. The apparatus used is described. Experimental results for the variation with temperature of the activity of FeO in iron oxide slags saturated with SiO_2 and CaO, respectively, are compared with those found by earlier workers.—K. E. J.

On the Desulphurization of Molten Steel by CaC_2 and CaO. K. Shimanaka et al. (*Tetsu to Hagane*, 1956, **42**, Sept., 864–865). [In Japanese]. In steel deoxidized by aluminium, CaC_2 reduces the sulphur content to approximately 0·002%, while CaO only brings it to 0·01% but in a slightly shorter time.

Use of Oxygen in the Open-Hearth Scrap-Ore Process. I. P. Bardin, K. G. Trubin, L. M. Efimov, K. M. Trubetskov, V. N. Kornfel'd, R. I. Men'shikov, and V. F. Mazov. (*Stal'*, 1956, (6), 493–505). [In Russian]. Trials on the use of oxygen in the O.H. furnace carried out during 1955 as part of a comprehensive co-operative research programme in the U.S.S.R. are described, in which both direct blowing of the baths and the enrichment of combustion air were included. Greatest reduction of tap-to-tap time was obtained when blowing was started early during melting and finished at a carbon-content of 0·08–0·10%. For the range of conditions studied the oxygen consumption was 5–12 m^3 per ton of steel, fuel consumption being reduced by up to 100 kg/t. When blowing is started soon after charging the liquid iron the rate of decarburization can overtake heating rates, and melting, and generally the optimal time for starting the blow depending on the particular conditions. Elevation of the oxygen content of combustion air to 30% is as effective as direct blowing for increasing productivity and gives improved heat utilization; roof and checker temperatures are raised but stay within safe limits. Compared with enrichment to 25% the tap-to-tap times for enrichment to 25–30% and 30% are decreased by 19% and 26%, respectively, but the yield of liquid steel falls. The slag is somewhat more oxidized, the gas content (O_2, N_2, and H_2) is not appreciably affected by oxygenation to 30%. Conditions at the Zaporozhstal' were not conducive to the fullest realization of the benefits of 30% oxygenation and optimal oxygenations for various conditions are discussed in the article.—S. K.

On the Distribution of Oxygen in Molten Steel during Refining Time. Y. Nagano et al. (*Tetsu to Hagane*, 1956, **42**, Sept., 854–856). [In Japanese]. The distribution of oxygen is investigated for up to 10 min after reversal of firing (melt-

down, after ore addition and before adding Fe–Mn), and at the different doors for the same periods. The distributions of total FeO in the slag and the temperature of the molten steel are similarly investigated.—K. E. J.

Studies on Improvement of Steel Quality by TiO_2 Slag Treatment. II. Some Considerations on the Ghost Zone of a Large Ingot. H. Hirano et al. (*Tetsu to Hagane*, 1956, **42**, Sept., 714–717). [In Japanese.] The sound part of the ingot, the central portion of the " ghost " and the portions surrounding the " ghost " were examined by macro-etching, sulphur prints, and Quantometer analyses of portions removed by a specified sampling technique. Results are given for total O, N, P, S, and Mn contents at stated locations.—K. E. J.

Study on the Sampling Methods of Molten Steel and Behaviour of C, Mn and S in Molten Steel from the Last Period of Refining to Ingot Making. Y. Kajikawa. (*Tetsu to Hagane*, 1956, **42**, Sept., 813–815). [In Japanese]. The significance is investigated of the relationship between carbon content in a general steel sample and that in aluminium-killed samples before adding Fe–Mn, of that between the latter carbon content and the carbon content in the ingot sample, and of that between a parameter including all three carbon contents and the product [C][FeO].—K. E. J.

Study on the Methods for Increasing [Roof] Life of Open Hearth Furnaces. S. Tamamoto et al. (*Tetsu to Hagane*, 1956, **42**, Sept., 734–735). [In Japanese]. With box type roofs, the life was increased by using basic and silica bricks instead of all silica bricks. With rib type roofs, the introduction of semi-super and super (" Zebra ") refractories led to longer lives. Brick consumption figures are quoted.—K. E. J.

The Relation of Open Hearth Foremen's Interpersonal Perceptions to Steel Production. W. A. Cleven and F. E. Fiedler. (*TIDU* 4785*A*; List 679, pp. 14). Evidence was found that the more effective groups had supervisors who perceived relatively large differences between their most and least preferred co-workers.

Results of Investigations Carried out During the Blowing Down and Raking Out of Furnace I at the J. W. Stalin Steel Works in September 1955. G. von Struve. (*Neue Hütte*, 1956, **1**, Nov., 515–524). When the furnace was shut down after 31 months' operation representatives of the Metallurgical Institute at Freiberg investigated internal damage. The stack brickwork, originally 600 mm thick, had disappeared almost completely. Deposits had formed instead to a depth of 1·25 m. The liquid phase was primarily involved in deposit formation in the wall batter of the stack; but not in deposit formation in the upper part of the stack. Excessive wear of the brickwork was attributed to inadequate cooling.—L. J. L.

Sulphurization from Fuel Oil. B. Trentini, A. Peters, and G. Husson. (*Iron Steel*, 1956, **29**, Dec., 537–542; 1957, **30**, Jan., 11–17). Fuel oils of varying sulphur content were used in the O.H. furnace for a range of steels made as far as possible under the same conditions. Oils with 0·45%, 1·85%, and 3·5% S were used with a total of 26 heats in a fixed 40-ton furnace fed with cold metal. The casts of 0·07% C steel were made with a period of 5 h 40 min from charging to tapping. Sulphur in metal and slag was determined. Full analyses are tabulated, and balances and slag-to-metal ratios are calculated. Sulphur partition is related to slag composition for which ternary diagrams are given. It appears that states near to equilibrium are attained.

A Process for the Effective Desulphurisation of Iron. B. Trentini, L. Wahl, and M. Allard. (*Centre Doc. Sidér. Circ. Inform. Tech.*, 1956, **13**, (11), 2213–2226). A new process for the desulphurization of liquid pig iron is described in which powdered lime suspended in nitrogen is blown through the iron via tuyeres in the bottom of a ladle. The operation is concluded in a few minutes and residual sulphur contents of less than 0·0010% are possible. (16 references).—B. G. B.

Desulphurization with Solid Lime. S. Eketorp. (*Rev. Mét.*, 1955, **52**, Sept., 718–724). Burnt lime in powder form is an effective desulphurizing agent provided that strongly reducing conditions and good contact between lime and pig iron are maintained. It is possible to lower the sulphur content of sponge iron at 850–900° C with lime from 0·3 to 0·03% with $\frac{1}{2}$ to 1 h treatment. Krupp–Renn sponge has been desulphurized from 0·63 to 0·065% in one hour at 1000° C. The practical application of this method in the Kalling Domnarvet process for desulphurization of molten pig-iron is discussed.

Study of Simultaneous Desulphurization and Deoxidation in a Fluorspar Crucible. W. A. Fischer and H. Engelbrecht. (*Rev. Mét.*, 1955, **52**, Oct., 785–792). In a non-oxidizing atmosphere in the presence of lime the desulphurization of iron–carbon alloys depends on the carbon content of the melt. Attempts have been made to reduce the content of oxygen dissolved in the iron by adding silicon to the steel melted in a high-frequency furnace. The influence of silicon and carbon on the rate of desulphurization was studied. The final sulphur content of steel melts depends exclusively upon the oxygen dissolved in the iron under the test conditions.—B. G. B.

Electric Arc Furnaces. F. S. Leigh. (*Iron Coal Trades Rev.*, 1957, **174**, Jan. 11, 83–90). Advances in design and construction, labour costs, and fuel prices and their effects in the establishment of the arc furnace in bulk steel production are described.

The First Half Century of Electric Furnace Steel Making. S. B. Casey Jun. (*J. Met.*, 1956, **8**, Dec., 1637–1641). The author reviews the evolution of electric-arc furnace design and discusses the development of electrical equipment and other changes which have helped to speed the operation. Probable future developments are also considered.—G. F.

Installation of a Magnesite Hearth in an Electric Arc Furnace. Luiz de Araujo. (*Radex-Rundschau*, 1956, May, 140–142). First two thermocouples are installed, one at the junction of the bricks and rammed material at the hearth centre and the other at the top surface of the brickwork at the inner end of the taphole. The hearth is bricked to shape (1 insulating and 3 magnesite courses plus stepped sides) and the surface treated with water glass. A selected grain-size grading of magnesite is mixed with 7% water, and spread in a layer 10 in. thick. This layer is rammed until 2 in. thick and the process repeated until the hearth contour is obtained. Warming up is slow (11 hours gas flame and electric arc on coke), until the centre thermocouple reaches 1200° C, the surface then being 1650° C. The hearth is costly but can withstand the high temperatures of oxygen lancing. Fettling consumption and times are less.

Arc Furnace Control. Improved Method of Arc Voltage Measurement. O. S. Steele. (*Elect. Rev.*, 1957, **160**, Jan. 4, 7–8). Arc control on electric arc melting furnaces can be inaccurate on low power factors, i.e. when a " cave-in " of metal occurs round the electrodes; in such cases accurate control is most desirable to minimize the risk of overloads. This is due to the fact that the voltage across the arc is not the same, under low power-factor conditions, as that between the transformer bus and the furnace shell. The paper describes a method of obtaining a correct arc voltage signal by adding a voltage, equal and opposite to reactance drop between the transformer bus and the arc to the signal voltage taken between the bus and the furnace shell. Practical tests have given good results.—L. D. H.

Steelmaking with a Small Arc Furnace and Properties of Experimentally Produced Steels. K. Kimura et al. (*Tetsu to Hagane*, 1956, **42**, Sept., 856–857). [In Japanese]. Slag compositions, mechanical properties of the steels after various heat treatments, the relation between C and O at the refining period, and the mechanical properties of aluminium-killed cold-rolled sheets are given.—K. E. J.

Rectifiers for the Steel Industry. R. J. Moran and A. Schmidt jun. (*Iron Steel Eng.*, 1956, **33**, Nov., 114–123).

Use of Vacuum-Powder Insulation in Transporting Gases in the Liquid Phase. G. Stüber and H.-J. Trauer. (*Technik*, 1956, **11**, Nov., 779–783). The theory and practical possibilities of improved thermal insulation for use in the transport of liquefied gases, are outlined with reference to the Smoluchowsky effect.—J. G. W.

Studies on the Application of the Consumable Electrode Method to Steel Melting. II. Melting of Low-Carbon Case-hardening Steel: Effect of Inner Pressure in the Furnace on [Ingot Formation]. T. Yukawa et al. (*Tetsu to Hagane*, 1956, **42**, Sept., 720–721). [In Japanese]. The furnace is described. With argon at pressures of 780, 50, and 10^{-2} mm of Hg in the furnace, neither V nor inverted-V segregation is observed in the ingot, and non-metallic inclusions are fewer at lower pressures. Details are given of hydrogen and oxygen contents at specified positions in the ingot.—K. E. J.

Studies on the Application of the Consumable Electrode Method to Steel Melting. II. Melting of Low-carbon Case-hardening Steel: Effect of Magnetic Circulation on [Ingot Formation]. T. Yukawa et al. (*Tetsu to Hagane*, 1956, **42**, Sept., 721–723). [In Japanese]. Comparative studies were made of steels melted under argon pressures of 780, 50, and

10^{-2} mm of Hg, in fields of 0, 30, and 50 gauss. The stronger the field and the higher the pressure, the deeper the pool of steel. Magnetic circulation has no effect on the cleanliness of the steel or the contents of Mn, O, H or N, whereas all these are reduced by decrease in pressure.—K. E. J.

Studies on the Application of the Consumable Electrode Method to Steel Melting. III. Melting of Austenitic Stainless Steel, Die Steel and Martensitic Stainless Steel. T. Yukawa et al. (*Tetsu to Hagane*, 1956, **42**, Sept., 723–725). [In Japanese]. Tests on steels of various compositions melted under argon pressures of 50 and 10^{-2} mm of Hg show that lower pressures lead to lower amounts of non-metallic inclusions and gas, sound ingots of 18–8 stainless steel, free from shrinkage pipes or pin-holes, were produced.—K. E. J.

Current Electric Furnace Practices at Atlantic Steel Company. J. E. Willbanks. (*Blast Furn. Steel Plant*, 1957, **45**, Jan., 50–52). The practice at this plant, which consists of two eighteen-foot shell top charge furnaces, is described. 90% of the steel produced is plain carbon, semi-killed steel ranging from 0·04 to 1·00% carbon. Rimmed and low alloy steels make up the balance. Each furnace averages 17 tons/h for each available hour operated. A plant production rate of 23,000 tons per month is obtained.—B. G. B.

Sponge Iron and H-Iron For Electric Furnace Charging. P. E. Cavanagh. (*J. Met.*, 1956, **8**, Dec., 1642–1644). The author discusses methods of producing and using virgin melting stock for electric steelmaking, and compares the relative merits of the different types available. There are iron ore, pig iron, blown metal, sponge iron, and " H-iron," which is an experimental type of sponge iron produced by hydrogen reduction using the fluidized bed technique.—G. F.

Desiliconized Pig Iron For the Electric Furnace—A Possibility. S. L. Case. (*J. Met.*, 1956, **8**, Dec., 1645). One factor against the use of high hot metal charges in electric steelmaking is the high silicon content of the charge. The author briefly reviews the advantages of desiliconizing the pig iron before charging, and indicates the important reduction in operating costs which would result.—G. F.

Degassing in the Basic Electric Arc Furnace Operation. I. Elimination of Hydrogen. Y. Kawamoto. (*Tetsu to Hagane*, 1956, **42**, Sept., 857–859). [In Japanese]. The variations of hydrogen content are traced during ore addition, bessemerizing, and lime (and limestone) addition periods.—K. E. J.

Induction Stirrers Upgrade Cast Steel. (*Steel*, 1956, **139**, Sept. 24, 132–133). Induction stirrers for use on 2 electric arc furnaces making alloys for casting are described. Benefits expected are noted.—D. L. C. P.

The Manufacture of Special Steels. G. R. Bashforth. (*Brit. Steelmaker*, 1957, **23**, Feb., 42–48). Systems of routine control for high quality steel production and precautions in the manufacture of deep-drawing steel are discussed. Raw materials, melt control, slag control, refining practice, deoxidation practice, and casting pit practice are considered in order with special reference to instrumentation, personnel training, and similar topics. (9 references).

Gain Quality, Trim Costs With Special Alloys. (*Steel*, 1956, **139**, Oct. 1, 156–162). The properties of special alloys are described and examples given of applications in which the special properties have proved valuable. Appended is a " metal selector " section, of tables listing the types, composition, properties, uses, and other details of 8 groups of alloys for special purposes.—D. L. C. P.

Specifications for Unalloyed Steels, as Manufactured in Italy According to the European Iron and Coal Community Production Program. G. Z. Zazinovich. (*Rev. Mét.*, 1955, **52**, Nov., 895–908). In order to facilitate the exchange of metallurgical products between member countries of the Community adequate knowledge of the different qualities of steel produced in each is essential. Full data for Italian unalloyed steels are given.—B. G. B.

Roxor, the Czechoslovak Concrete-reinforcing Steel. J. Korecký. (*Czech. Heavy Ind.*, 1956, (1), 10–12). Compositions and properties of the two grades are given and the weldability of the ČSN grade 10513 steel is discussed.

Developments in Alloy Steels. G. J. Harris. (*Financial Times Survey*, [1957], 35–36). A general account of types and alloying elements.

Manufacture of High-tensile, High-notch-tough Steel. I. On a Preliminary Examination and Trial Manufacture. K. Miyano et al. (*Tetsu to Hagane*, 1956, **42**, Sept., 830–832). [In Japanese]. The micro-structure of the steel (composition given) is analysed by optical and electron-microscopical means, for the as-rolled, direct-quenched, and direct-quenched-and-tempered conditions.—K. E. J.

Manufacture of High-tensile, High-notch-tough Steel. II. Test Results. K. Miyano et al. (*Tetsu to Hagane*, 1956, **42**, Sept., 832–833). [In Japanese]. Results are given for the Kinzel test, and for the effects of strain (2·5, 5, and 10%) and strain-ageing on the V-notch Charpy value at − 20° C.

Steels and High Temperature Alloys. G. Grenier. (*Echo Mines*, 1956, Dec., 711–712). A short review of the various types of steels or metal alloys suitable for use at high temperatures is presented. The properties of a number of materials are given in tabular form.—B. G. B.

Some Considerations of Service Properties of High-tensile Steels. K. Terai et al. (*Tetsu to Hagane*, 1956, **42**, Sept., 829–830). [In Japanese]. The effects of finishing roll temperatures between 650° and 900° C on the tensile properties of the two sides of the steel specimen (composition given) are described. Transition curves are given for the DVM impact testing of the steel formed with rolls at 740 ∼ 930° C, 22 mm thick, in the as-rolled and 8% strain-aged conditions.—K. E. J.

Super-High Strength Constructional Steels. H. P. Tardif. (*Steel Processing*, 1956, **42**, Dec., 702–704, 709). The development and properties of these steels are described and their compositions and mechanical properties and heat treatments tabulated.

Ultra High Strength Steels. J. W. Sands and O. O. Miller. (*Mat. Methods*, 1956, **43**, Mar., 94–98). A survey of production and experimental compositions and the possibility of obtaining 350,000 psi steel. Uses and trends and the danger of embrittlement are discussed.

The Supply of Nickel. (*Financial Times Survey*, [1957], 39). **Developing the Uses of Nickel.** (40). Stainless and alloy steels are briefly referred to.

Technical Effects on Special Steels of Fluctuations in the World Production of Nickel. A. Michel. (*IVe Salon de la Chimie.—Journée des Aciers Spéciaux, Versailles*, Nov., 1956, pp. 15). Steels containing nickel, constructional, oxidation-resisting, and heat-resisting are briefly reviewed and the effects of nitrogen and manganese are considered. The above classes are then discussed in greater detail.

On Hydrogen Content of Molten Steel. S. Sato et al. (*Tetsu to Hagane*, 1956, **42**, Sept., 788–790). [In Japanese]. Relationships are shown between the partial pressure of water in the atmosphere at pouring and the hydrogen content of Ni–Cr stainless steel and high-Cr heat-resisting steel. Refining methods to reduce the hydrogen content include oxygen blowing for specified periods.—K. E. J.

Studies of Heat-resisting Steels. XII, XIII. E. Asano. (*Tetsu to Hagane*, 1956, **42**, Sept., 846–847; 847–848). [In Japanese].—K. E. J.

On the Extraction of Chromium in the Steel-making Process for 13-Cr Stainless Steel. S. Dateyama et al. (*Tetsu to Hagane*, 1956, **42**, Sept., 863–864). [In Japanese]. The influence of carbon content on chromium content after oxygen blowing (temperatures of 1675°, 1725°, and 1750° C), and the relationship between reduced and oxidized chromium for various Fe–Si additions, are traced.—K. E. J.

The Special Steel-maker and Power Generation. C. Sykes. (*Iron Steel*, 1957, **30**, Feb., 69–73). Steels for power station use are described.

Studies on Ingot Feeder Heads. H. S. Marr, G. Fenton, and W. H. Glaisher. (*J. Iron Steel Inst.*, 1957, **187**, Oct., 81–92). [This issue.]

Steelworks Ingot Moulds. J. Durand. (*Arts et Manuf.*, 1957, Jan., 40). An account of measures to increase the service of moulds.

Study of Steel Ingot Moulds. J. Duflot and M. Ferry. (*Génie Civil*, 1957, **134**, Jan. 15, 33–34). A paper given in the ANRT Journée d'étude sur la rentabilité de la recherche, Nov. 1956. A review of topics for research is given.

The Safe Coupling of Ingot Casting Cars and Scrap Pan Bogies. (*British Iron and Steel Federation, Sub-Committee Report*, 1956, pp. 40).

Casting Pit Equipment. Repair by the Thermit Process. A. M. Hamilton. (*Iron Steel*, 1957, **30**, Feb., 74–75). Methods developed at Clydebridge Works, Cambuslang, are described.

Some Consideration of Bottom Pouring. S. Yabuuchi. (*Tetsu to Hagane*, 1956, **42**, Sept., 853–854). [In Japanese].

Practical Study on Low-Carbon Rimmed Steel Making. I. Phenomena of Rimming Steel and the Relation between the

Degree of Rimming Action and the Form of Ingot-Head. K. Izu et al. (*Tetsu to Hagane*, 1956, **42**, Sept., 735–738). [In Japanese]. The discussion includes consideration of the relationship between the oxygen content in the steel and the rimming action, and of the increases in sulphur, phosphorus, and oxygen contents and the decreases in manganese and carbon contents in the liquid interior of an 8-ton ingot as the time after filling the mould increases to 28 min.—K. E. J.

Study on Ingot-Making Practice. V. Effect of Oxidation of Molten Steel by Air on the Non-metallic Inclusions in Steel. 4. Oxidation Velocity of Various Elements During Pit Practice. Y. Nakagawa et al. (*Tetsu to Hagane*, 1956, **42**, Sept., 852–853). [In Japanese]. The variations of C, Si, Mn, and Al with time (0–45 min) at 1520° and 1600° C are shown, and thermodynamic data are deduced for the oxidation of these elements.

Study on the Temperature of Liquid Steel in Tapping and Casting Practice. T. Ooka et al. (*Tetsu to Hagane*, 1956, **42**, Sept., 749–751). [In Japanese]. Cooling curves are given for bottom-poured low-carbon steel, between addition of ferromanganese in the bath and 15 min after casting, for ladles with and without slag cover. The relationship between the temperature of the ladle before tapping and the weight of ladle skull is shown: the skull decreases as temperature increases.—K. E. J.

Exothermics Raise Ingot Yields. Improvements in Hot Top Linings and Design. G. N. Cherry. (*Brit. Steelmaker*, 1957, **23**, Jan., 12–15). An illustrated account of the avoidance of cropping losses. Refractory linings and hot topping practice is described.

Aluminium Rod Upgrades Killed Steel. E. Long and B. E. Brennan. (*Steel*, 1956, **139**, Sept. 24, 124–126). The deoxidation of steel by the use of commercially-pure aluminium rods fixed in the mould before pouring, is described. The method gives advantages in economy, steel quality, and surface condition.—D. L. C. P.

On the Variation of Oxygen and Aluminium in Molten Steel during Pouring Practice. T. Obinata et al. (*Tetsu to Hagane*, 1956, **42**, Sept., 860–861). [In Japanese]. The effects of sampling practice (various spoon positions, from the slab, or cast direct) on the results for oxygen content and acid-soluble and insoluble aluminium are discussed for rimming, semi-killed and killed steel. For the same steels, the variations in oxygen content throughout pouring are traced.—K. E. J.

Studies on Improvement of Steel Quality by TiO_2 Slag Treatment. III. Effect of TiO_2 Slag Treatment on the Ghost Zone of a Large Ingot. T. Shimose et al. (*Tetsu to Hagane*, 1956, **42**, Sept., 717–720). [In Japanese]. Thermodynamic data are given for the equilibria between Ti, Si, Cr, Mn, Fe, and V and their oxides, and for the reduction of the oxides by aluminium. Experimental data are given for contents of titanium and sulphur in various forms in steels melted at various temp. between 1550° and 1710° C.—K. E. J.

Cast Stainless Alloy is Stronger, More Resistant Than 18–8. (*Mat. Methods*, 1957, **45**, Apr., 172). An account of CD–4MCu, a 25–27% Cr, 4·75–6% Ni, 1·75–2·25% Mo, 2·75–3·25% Cu steel, with a table of properties is given.

Investigation on Acid-Resistant High-Silicon Iron. II. H. Sawamura, O. Tajima, and K. Akamatsu. (*Mem. Fac. Eng., Kyoto Univ.*, 1956, **18**, July, 280–313). Effects of Mn, P, S, Ni, Co, Cr, Mo, W, V, Ti, Al, Cu, Sn and As on the mechanical properties, corrosion-resistance and shrinkage of high-silicon irons have been investigated. Complex relations to microstructure were observed.

Properties of Some Tungsten and Titanium Steels Containing Boron. A. Banerjee, D. K. Sood, and P. Mehta. (*Trans. Indian Inst. Met.*, 1955–56, **9**, 143–160). Mechanical and weldability tests were carried out on boron-containing low-carbon (0·12%) steels with and without either 0·08–1·46% Mo, 0·07–2·3% W or 0·09–1·08% Ti after normalizing from 920° C. All steels had similar weldability when tested in the Reeve fillet-weld test. The W and Ti steels showed no advantages over the Mo-containing steels.—D. H.

Steels for High Pressure Casting Dies and Moulds. H. Hiller. (*Giesserei*, 1957, **44**, March 14, 141–149). Hot working tool steels are considered in general terms, including a description of the effect of alloying elements. The influence of stressing due to thermal cycling is described. Steels for high pressure dies and moulds are tabulated together with their chemical compositions. Mechanical properties of die steels, such as the strength in service and the susceptibility to hot cracking are compared and the effect of heat-treatment, nitriding, and thermal stressing discussed.—R. J. W.

PRODUCTION OF FERROALLOYS

New Process Puts Higher Profit in Low Grade Ores. (*Iron Age*, 1957, **179**, Apr. 4, 102–103). **Ferromanganese From Low-Grade Ores.** J. J. Burke. (*J. Met.*, 1957, **9**, Mar., 340–342). A new prototype plant at Niagara Falls promises economic production of ferro-manganese and iron from ores averaging only 12–13% Mn and 15–20% Fe. The process, developed by Udy, is one of selective reduction with heat economy, and a brief outline is given.—G. F.

Some Observations on the Slag–Metal Equilibria Involved in Ferromanganese Production. N. J. Wadia, V. G. Paranjpe, and S. Visvanathan. (*Trans. Indian Inst. Met.*, 1955–56, **9**, 83–109). Slag–metal equilibria in manganese-rich burdens were investigated to ascertain the effects of Mn content of the metal, slag composition and basicity, and temperature on the Mn and S distribution coefficients. It was found that the desulphurization reaction follows the same pattern as in iron making with the exception that the slags have a higher sulphur bearing capacity. The S distribution coefficient is little affected by increasing the S input to the charge but the Mn efficiency is lowered.—D. H.

FOUNDRY PRACTICE

Foundry Grows in the North. (*Canad. Metals*, 1956, **19**, Dec., 16). A short account of extensions recently made to the Wabi Iron Works Ltd., New Liskeard, Northern Ontario, is given. The principal output of the foundry is Ni-Hard castings for the mining industry.—B. G. B.

Tools for the Foundry of Tomorrow. (*Mod. Castings*, 1956, **29**, June, 63–78). Notes on tools or machines for green sand moulding, sand conditioning, coremaking, metals, fluxes and refractories, melting and pouring, shakeout, cleaning and finishing, for materials handling, and for safety, hygiene and control of air pollution are presented; also for shell moulding, testing and inspection and other operations.

Craftsmanship in Casting. (*Foundry Trade J.*, 1957, **102**, May 16, 605–608). An account of the Cardiff Foundry and Engineering Co. (1947) Ltd. modernization for the production of high-quality grey castings is given. The article records the impressions of a visitor new to the trade.

8 Rules to Save Bottom Boards. M. Applefield. (*Mod. Castings*, 1956, **30**, Nov., 32–33). Elimination of joints and water-glass treatment, avoiding damage during handling, keeping sufficient depth of sand to reduce heat intensity and other recommendations are made.

The Foundry of Tomorrow. (*Mod. Castings*, 1956, **29**, May, 89–112). Suggestions for lay-out, handling, new control apparatus, melting, core-making, moulding, sand treatment heat treating, and finishing processes of highly advanced designs are shown, dated A.D. 2001.

A $7 Million Foundry. (*Mod. Castings*, 1956, **30**, Sept., 28–29). A brief account of the Bullard Co. foundry at Bridgeport, Conn. is given.

Two Grey-Iron Foundries. M. M. Hallett. (*Foundry Trade J.*, 1957, **102**, May 16, 597–602). The foundries of Chamberlin and Hill Ltd. and their products are described.

How to Improve Foundry Layout. R. B. Sinclair. (*Mod. Castings*, 1956, **30**, Dec., 35–46). Plans and illustrations are given with discussion.

Aids to Production in a Jobbing Foundry. I. Rees and D. H. Snelson. (*Brit. Found.*, 1957, **50**, May, 267–288). The core-assembly method, CO_2 process, and use of mouldable-type exothermic feeding compound are discussed. Conditions necessary for obtaining directional solidification are demonstrated and design of feeding heads described, and its limitations.

Production Problems in the Manufacture of Alloy-Iron Castings. W. M. Lord. (*Brit. Found.*, 1957, **50**, May, 258–267). Improvements in a small foundry are outlined, both by installation of new plant and by using new processes. A sandslinger moulding unit and a motorized turnover machine are described. Two cupolas have been converted to water cooling and spheroidal iron is produced by the autoclave process. Control and planning are discussed.

Case Study Report on 3 Small Gray Iron Shops. (*Mod. Castings*, 1956, **29**, Jan., 41–56). A condensed account of a report on 5 foundries issued by the U.S. Dept. of Labor. Foundries employing 47, 53, and 53 persons are described.

Designing Gray Iron Castings. A. Scharf and C. F. Walton. (*Machine Design*, 1957, **29**, Jan. 10, 104–122). A comprehensive review with sections on methods, properties (tensile, compressive and yield strengths, elasticity, endurance limit, elongation and ductility, hardness, machinability, castability and wear and corrosion resistance), design of castings and cost factors linked with a commentary on more general lines. The article is based on a forthcoming book.

Basic Considerations on Melting in Cupola Furnaces. A. Dahlmann. (*Giesserei*, 1957, **44**, Jan. 31, 79–81). The combustion processes that take place during melting in a cupola are described. Diagrams are given showing the isothermal values and gas compositions (CO_2, CO, and O_2 contents) through a vertical cross section of a cupola. Figures are tabulated showing the rapid rise in coke costs for a higher temperature for the molten iron. The variation of temperature with time is shown graphically. (5 references).—R. J. W.

Cupola Charging Speeded to Break Production Barrier. H. G. McCallum. (*Mod. Castings*, 1956, **29**, Mar., 30–33). Improved make-up, handling, and skip charging arrangements are described.

Measurement and Control on Cupolas. W. Ruppert. (*Giesserei*, 1957, **44**, March 14, 153–160). Methods of measuring the volume, pressure and humidity of the air blast are described and illustrated with diagrams. Analysis and temperature measurement of the throat gas and of the melt are described separately. An instrument for controlling the volume of the air blast is also described. Similar measurements can be made on hot blast cupolas, with the blast heated by (*a*) the sensible heat of the throat gas, (*b*) the combustion of the throat gas or (*c*) the combustion of other gases. Measurements of various pressures and temperatures are described.—R. J. W.

Dehumidification of the Cupola Blast. F. W. Jacobs. (*Foundry*, 1957, **85**, May, 174–177). The operation of an 80 t unit is described and the economies achieved are evaluated.

Special Cupolas and Accessories. (*Mod. Castings*, 1955, **28**, Nov., 41–52). A review with diagrammatic sections and lay-out plans.

A New Idea—Warm Blast Cupolas. W. Y. Buchanan. (*Mod. Castings*, 1957, **31**, Jan., 40). A blast heated to 140° F by a recuperative system, used by John Lang and Sons Ltd. is outlined.

Charting the Way to Cupola Quality Control. M. Gittleman. (*Mod. Castings*, 1957, **31**, Feb., 58–60). A record system is described.

Radioactive Gage Aids Cupola Stock-Line Control. H. A. Tuttle, G. E. Noakes, and T. R. Thomas. (*Foundry*, 1957, **85**, May, 178–179). The development of the dual level γ-ray gauge is described.

Limestone Carbonic Acid in the Cupola. H. Jungbluth and A. Dahlmann. (*Giesserei*, 1957, **44**, Jan. 3, 7–13). The various ways of eliminating the limestone CO_2 from the cupola are discussed. Approximate methods for calculating this elimination are described, together with a determination of the errors likely to be incurred. Special slide-rules and nomograms for the determination of CO_2 and the wind volume are illustrated and their method of use described. Finally, the conversion of the wind volume to normal conditions is described.—R. J. W.

How Design and Operation Influence Cupola Emission. R. C. Ortgies. (*Mod. Castings*, 1956, **29**, June, 54–56). Discharge from the stack under various conditions was sampled, and findings are reported.

The Chemical Analysis of Cupola Slags. Part 1. The Determination of Alumina. (a) The Fluoride Method. W. E. Clarke. (*Brit. C.I. Res. Assoc. J. Res. Dev.*, 1957, **6**, Feb., 505–511). A direct fluoride volumetric method is described for the determination of alumina in cupola slags. (16 references).

Oil-Fired Melting Furnaces. (*Metallurgia*, 1957, **55**, Mar., 128–130). A review of factors governing the design of installations for supplying oil fuel for melting furnaces is presented.

How We Solved Our Hot Cracks Problem. F. W. Jacobs. (*Mod. Castings*, 1955, **28**, Oct., 30–36). Duplex process malleable iron, its production and analysis, are described and hot cracking faults occurring are described and illustrated. Conditions for their elimination are carefully analysed. It is concluded that oxide content must be held within a defined range. It can be controlled by watching cupola and furnace slag colour, the higher the oxide the darker they become, and they can be analysed for FeO as a check, 5–6% FeO and 12–15% in the furnace slags are maintained. Fluidity is checked by periodically pouring standard tests.

Shrinkage Defects in K-Bar Test Castings. J. Gittus. (*Brit. C.I. Res. Assoc. J. Res. Dev.*, 1957, **6**, Feb., 456–483). The results are given of a study of the simultaneous effects of nine variables upon the surface shrinkage of K-bar castings. The conditions of study approached those obtaining in a foundry where defects may arise from a combination of causes. The variables studied are: maximum furnace temperature, time interval charge to tap, average pouring temperature, shatter index of sand and the iron analysis (C, Si, Mn, S and P).—B. G. B.

Factors Relating to the Stress/Strain Properties of Cast Iron. G. N. J. Gilbert. (*Brit. C.I. Res. Assoc. J. Res. Dev.*, 1957, **6**, Apr., 546–587). Stress–strain properties and mechanism of failure are considered by regarding cast iron as steel + graphite. Breaking strength depends on the notch effect of graphite and its reduction of cross section. Deformation is partly elastic and partly plastic and methods of obtaining modulus of elasticity are given. The bending of beams is then considered.

Foundry Maintenance. P. W. Pegg and L. R. Evans. (*Brit. Found.*, 1957, **50**, Apr., 197–201). Service department organization and training and bonus payment of maintenance staff are discussed.

Carbon Arc Blast Smooths Rough Surfaces. F. Newberry. (*Mod. Castings*, 1956, **29**, May, 121–122). Oklahoma Steel Castings Co. practice is outlined.

Flame Washing of Steel Castings. A. F. Chouinard. (*Welding J.*, 1957, **36**, March, 219–224). The flame washing method is described. It is mostly applied in foundries for the removal of riser pads, fins, drill bars, reinforcement rails and core chaplets, and is also used for the removal of sand inclusions and penetrations.—U. E.

The MTM Method and Its Application to a Foundry. I. Edman. (*Giesserei*, 1957, **44**, Jan. 31, 65–75). The principles of the Methods–Time–Measurement system are enumerated and an example of an MTM analysis given and its use to produce better castings is described. The machine-moulding of brake drums is used as an example of its application. The employment of the MTM system for the pre-determination of work standards and for the simplified determination of job times is described at length.—R. J. W.

Nodular Iron and Nodular Lung Shadows. H. J. Weber. (*Mod. Castings*, 1956, **30**, Dec., 56). Silicosis and siderosis are distinguished.

The Noise Problem in Foundries. (*Mod. Castings*, 1956, **29**, Mar., 37–52). Hearing, legal responsibilities for impairment in workers, sources of noise, measurement, clinical supervision and suppression of noise are discussed.

VACUUM METALLURGY

The Effect of Final Annealing under High Vacuum on the Magnetic Reversal Losses of Hot- and Cold-Rolled Transformer Plate. F. Lihl. (*Arch. Eisenhüttenwesen*, 1957, **28**, Apr., 223–226). Investigations of structure and measurements of magnetic reversal losses were undertaken in order to determine whether final annealing under high vacuum of transformer plate having 4·3% Si and 0·25% Al led to a reduction of magnetic reversal losses compared with annealing in a N_2–H_2 mixture, or using pure H_2 as a protective atmosphere. No "over-annealing" occurred in hot-rolled plate; in cold-rolled plate, annealing under high vacuum promoted crystal growth and the formation of recrystallization texture advantageous for magnetic properties.—L. J. L.

REHEATING FURNACES AND SOAKING PITS

Automatic Control of Soaking Pits. C. W. Cawthorne. (*Instrument Practice*, 1957, **11**, Apr., 349–352). The system used by Samuel Fox and Co. Ltd. at Stocksbridge is described.

Operation of Huge Reheating Furnaces at Weirton Steel Aided by Industrial Television System. (*Indust. Heating*, 1957, **24**, Jan., 92–94, 100). A closed-circuit T.V. system is used to assist the charging and heating of large slabs.—A. D. H.

Stone Pit Lining Experience at Ford. W. J. Scharfenaker. (*Iron Steel Eng.*, 1957, **34**, March, 98–104). The author describes the use of a natural quartz rock for lining soaking pits at the Ford Motor Co. The advantages and drawbacks of the stone are discussed and details are given of the soaking pit construction.—M. D. J. B.

HEAT-TREATMENT AND HEAT-TREATMENT FURNACES

The Industrial Heating Industry Faces 1957 With Confidence. C. L. Ipsen. (*Indust. Heating*, 1957, **24**, Jan., 29–34). A review of examples of plant installed in U.S.A. in 1956.

Heat Treatment of Carbon and Low-Alloy Pressure-Vessel Steels. O. R. Carpenter and C. Floyd. (*Welding J.*, 1957, **36**, Feb., 67s–76s). A report is given of the requirements prescribed by the A.S.M.E. Boiler and Pressure Vessel Code for the various steels commonly used for pressure vessels, together with the reasons underlying these requirements. Recommended practice for each of the various classes of steels is described.—U. E.

On Dimensional Changes of Carbon Steel Bars due to Heating and Cooling. II. H. Sekiguchi, M. Inagaki, S. Miyajima, and H. Watanabe. **III. Effect of Dimension of Bar.** M. Inagaki. (*Nippon Kinzoku Gakkai-Si*, 1955, **19**, Oct., 605–608; 608–612). [In Japanese]. II. The relations between the dimensional changes and the $A_1 \rightarrow A_3$ or Acm transformations were investigated. With extremely large or small rates of heating or cooling, the changes in low-carbon steel bars are small, compared with intermediate rates; the banded structure probably influences the changes. III. When the bars are long and slender, their lengths tend to decrease with heating and cooling, regardless of carbon content, but the effect is constant when the length/diameter ratio exceeds a certain figure. As the shape approaches that of a sphere, the changes become smaller. The changes, generally, are influenced by carbon content, microstructure, and bar dimensions.—K. E. J.

Steel Heat Treatment and Furnace Atmosphere. (*Mech. World*, 1957, **137**, Mar., 127–129). A review with a table of heat treatment for ferrous metals and an account of atmosphere compositions.

Conditioning Phenomena in a High Chromium Steel. S. C. Das Gupta. (*Trans. Indian Inst. Met.*, 1955–56, **9**, 207–217). Conditioning phenomena were investigated in a 15% Cr, 0·7% C steel under the following conditions: (*a*) with and without initial martensite, (*b*) in plastically deformed specimens without initial martensite. Degree of conditioning increased with temperature of reheating above 300° C. In the presence of initial martensite a change in the mode of formation of some martensite plates occurs above 450° C. The edges of previously formed plates appear to act as nucleation sites for further martensite formation.—D. H.

On the Change of Magnetic Intensity of High-C High-Cr Steel by Heat Treatments. K. Yokoyama and T. Matsukura. (*Nippon Kinzoku Gakkai-Si*, 1954, **18**, Oct., 539–542). [In Japanese]. The intensity of magnetization after quenching became smaller as quenching tempering rose, and was almost nil with a quenching temp. of 1130° C; this indicates a state of nearly 100% austenite. Specimens quenched from 950° or 1050° C exhibited an increase in intensity of magnetization at 300° C, and a marked change at 700° C, corresponding with the $\gamma \rightarrow \alpha$ transformation. The results show that the transformation of austenite is eased by lower quenching temp., higher tempering temp. and longer tempering times.—K. E. J.

Mains Frequency Induction Heating in Industry. T. S. Schaetzel. (*Electr. Eng. Merchandiser*, 1957, **33**, Feb. 20, 321–324). A review of power factor, depth of penetration, stirring and pinch effect with a note on uses.

Isothermal Transformation in Relation to Heat-Treatment of Steel. C. E. Mavrocordatos. (*J. South African Inst. Min. Met.*, 1956, **57**, Dec., 305–327). A review with discussion. (42 references).

Heat Treatment Diagram for A.I.S.I. 5140. D. J. Blickwede and R. C. Hess. (*Metal Progress*, 1957, **71**, Mar., 96B). The complete diagram for this steel austenitized at 1550° F is given. The composition is 0·46 C, 0·27 Si, 0·84 Mn, 0·87 Cr, 0·17 Ni.—B. G. B.

Heat Treatment Diagram for A.I.S.I. 9840. D. J. Blickwede and R. C. Hess. (*Metal Progress*, 1957, **71**, May, 96B).

Electric Furnaces for Carburising and Heat Treating. Review of Modern Practice in Germany. T. Türk. (*Metal Treatment and Drop Forging*, 1957, **24**, May, 199–200). Carburizing and carbo-nitriding, the Homocarb process using benzene-ethanol and the continuous and revolving hearth furnaces are reviewed.

Carburize, Martemper Parts in Single-Line Setup. C. E. Kopp. (*Iron Age*, 1957, **179**, Feb. 28, 82–83). A description is given of Evinrude Motors' recently installed mechanized salt bath line for the combination carburizing and martempering of outboard motor crankshafts. The sequence of operations is also outlined.—G. F.

Studies of the Effect of Methane in Heat Treating Furnace Atmospheres. (*Indust. Heating*, 1957, **24**, Jan., 56–58, 62). Recording infra-red gas analysis equipment used to determine up to 1% CH_4 is described.—A. D. H.

Restoring Carbon Cuts Fastener Failures. (*Steel*, 1957, **140**, Apr. 29, 186, 189). Steel screws are recarburized in a controlled-atmosphere furnace.

Commercial Bright Hardening of Stainless Steels. F. Hunter. (*Indust. Heating*, 1957, **24**, Jan., 205–212). The design and operation of a gas-fired continuous muffle furnace having a protective atmosphere of 75% H_2, 25% N_2 with a dewpoint of − 58° F is described.—A. D. H.

Gas Cementation in Medium and Small Series Production. O. Dorigo. (*Rivista Mecc.*, 1955, **6**, Oct. 1, 7–12). [In Italian]. The advantages of cementation by gases are discussed and the techniques are described. The author shows that cementation costs can be reduced to almost a third by using propane and ammonia enriched air.—M. D. J. B.

On Physico-chemical Research on Metallurgical Reactions. VII. Effect of Some Gases on the Reaction of Steel. Effect of Ammonia—2. S. Uchida. (*Nippon Kinzoku Gakkai-Si*, 1953, **17**, Sept., 438–441). [In Japanese]. Steel was carburized under various conditions in an atmosphere produced by burning charcoal in damp air and intermixing ammonia. The same degree of carbonitriding was produced with a lower gas velocity than in normal carburizing. The amount of carbonitriding increased with increase of ammonia at lower temperatures, but decreased at higher. Sooting decreased at all temperatures with ammonia additions.—K. E. J.

Applications of Oxy-Acetylene Flame-hardening. A. F. Chouinard. (*International Acetylene Association Proc.*, 1951–55, 1956, 282–288). The metallographic basis for the process is outlined.

On the Application of [Town's] Gas for Bright Heating and Carburising of Steel. II. On Carburising of Steel with Converted Gas. S. Uchida. (*Nippon Kinzoku Gakkai-Si*, 1953, **17**, Oct., 505–508). [In Japanese]. Experiments showed that town's gas could be converted to give good carburizing properties, provided that air ratios were adjusted to give low contents of CO_2 and H_2O, and considerable amounts of CH_4 and H_2. (14 references).—K. E. J.

Gas Carburising by the "Homocarb" Process. D. A. Colwell. (*Australasian Eng.*, 1956, **48**, Aug. 7, 60–63). A description of the furnace, carburizing media, and notes on operation are presented.

The Carburising Action of Various Carburising Agents. K. H. Kopietz. (*Härterei-Tech. Mitt.*, 1956, **10**, Sept., 9–37). The author discusses the factors affecting carburization and the properties of carburizing agents, the latter being classed into four groups. Every carburizing agent is denoted by its carbon value and carbon activity which are related to the carburizing properties of the steel, i.e. the diffusion coefficient for carbon and the saturation value of carbon in austenite. Variables are discussed. (26 references).—R. P.

The Practical Use of Carburised Parts in Assessing Carburising Agents. K. Kallhardt. (*Härterei-Tech. Mitt.*, 1956, **10**, Sept., 39–53). Results of tests are given which show that the carbon value of the carburizing agent is usually sufficient for assessing its efficiency provided the C-value is below the saturation limit of the steel. If the C-value lies above this saturation value the C-activity of the carburizing agent is important. An apparatus for testing the activity of solid carburizing agents by means of CO_2 is described.—R. P.

Study on the Case-Hardening of Stainless Steels. II. Study on the Nitriding of Austenitic Stainless Steel and Corrosion Resistance. K. Yamanaka et al. (*Tetsu to Hagane*, 1956, **42**, Sept., 773–775). [In Japanese]. For nitriding temperatures of 550° and 850° C, the variations of micro-hardness with case depth are shown for times of 25, 50, 75, and 100 h. The hardness is greatest at a nitriding temp. of 550° C and falls as this temp. increases to 850° C.—K. E. J.

Tests on Case-hardened Alloy Steels. W. Breuer. (*Härterei Tech. Mitt.*, 1956, **2**, Sept., 9–24). This paper gives a critical survey of the properties to be achieved with case-hardened alloy steels. It is pointed out that no relation seems to exist between the mechanical properties discussed. Further work in this field is suggested.—R. P.

Surface Hardening of Metals. (*Usine Nouvelle*, 1956, **12**, Oct. 25, 93–94). A brief review of flame and induction hardening and of developments in France and U.S.A.

Metals for Surface Hardening with Oxy-acetylene. (*Tecn. Indust.*, 1956, **34**, Sept., 1308–1310). [In Spanish]. A list of 10 alloy steels which, in addition to the 0·35/0·45% carbon steels, are suitable for surface hardening is given and discussed briefly. The effect of this treatment upon the mechanical and metallurgical properties, its tendencies to cause distortion, and its economic advantages are reviewed. A service life 4–5 times longer is obtained by this technique.—P. S.

Conditioning Steel with a Flame. J. F. Mayberry and T. G. Lutz. (*International Acetylene Association Proc.*, 1951–55, 1956, 343–348). Chipping and scarfing processes are discussed.

The Application of Induction Heating to the Surface Hardening of Steel. J. Hamilton. (*Metallurgia*, 1957, **55**, Jan., 3–7). An outline of the principles underlying induction heating is first given. Aspects affecting the practical application and types of generator available are discussed together with a description of typical installations.—B. G. B.

A Study on Induction Hardening. II. Experiments on Distortion. K. Nagaoka. (*Tetsu to Hagane*, 1956, **42**, Sept., 893–895). [In Japanese]. Factors such as the variation of strain at the outer extremities of the diameter and of the hardness with heating time and power input per unit area are discussed.—K. E. J.

Note on High Frequency Heat Treatment of Small Ferrous Metal Parts. P. Nucci. (*Rivista Mecc.*, 1955, **6**, July 2, 12–16). [In Italian]. The author describes the principle of high-frequency heating, the techniques involved in using this principle for heat treatment, the advantages of the method and the type of equipment to be used. Finally the results obtained are discussed.—M. D. J. B.

Stripe Phenomenon in Surface Heating by High-frequency Electromagnetic Induction. J. Pomey, J. Georges, and L. Abel. (*Compt. Rend.*, 1956, **243**, Nov. 26, 1745–1747). A steel cylinder heated by a uniform induction field develops temperature striations due to magnetic transformations of the first or second order. A differential method of study of carbide dissolution is deduced.

New Computation Method for the Determination of Thermal Fields in the Inductive Heating of Metals. H. Lachner. (*Metall*, 1956, **10**, Oct., 930–932). A formula for calculating the temperature distribution in metals being heated by induction is presented, due to Dr. F. Pelz, which is claimed to give results corresponding more closely to actual temperatures than the Schmidt method.—J. G. W.

High-frequency and Electronics in the Service of Metallurgy. C. Freteur. (*Usine Nouvelle*, 1956, **12**, Aug. 16, 53, 55). A review of equipment used for forging, hardening, and brazing and of U.S. firms carrying out such operations.

The Future of Carbonitriding. B. Jousset. (*Usine Nouvelle*, 1957, **13**, Jan. 10, 81–83, 85). An illustrated account of the furnaces and apparatus for producing the atmospheres used, with a list of uses and some suggestions as to possibilities.

Iron Nitriding near the Ferromagnetic Curie Point and its Application to the Nitriding of Some Alloyed Carbon Steels and Certain Nickel–Cobalt Alloys. G. Nury and H. Forestier. (*Rev. Mét.*, 1955, **52**, Oct., 816–820). Evidence that the nitriding velocity of iron in ammonia shows two accentuated maxima at 740° C and 760° C is given. The first one is considered to be due to the magnetic transformation phenomenon of an iron–nitrogen solid solution and the second one to the iron Curie point. Under similar test conditions alloyed carbon steels and nickel cobalt alloys showed similar results.

Liquid Salt Nitriding Produces Cheaper, Hardened Case for Stainless. H. A. Johnson. (*Western Metals*, 1956, **14**, Sept., 69–70).

Nitrided Chromium for Wear Applications. S. W. McGee and C. H. Sump. (*Amer. Soc. Test. Mat. Bull.*, 1956, Oct., 58–62). The development of a satisfactory hard wear-resistant surface by nitriding chromium coatings is described. The surface gave the best wear resistance of a variety of materials tested for service in oxygenated water at 500° F. The resistance of the surface was similar to chromium itself.

On the Scaling of Pure Iron and Scaling in General. N. G. Schmahl, H. Baumann, and H. Schenck. (*Arch. Eisenhüttenwesen*, 1956, **27**, Nov., 707–713). Tests have been carried out on electrolytic iron with oxygen at temperatures from 910 to 950° C. The effect on scaling constants and iron structure of various pre-treatments of the electrolytic iron has been investigated. Results differ little from those obtained by M. H. Davies et al. (*J. Metals*, 1951, (3), 889; (4), 536).—L. J. L.

Kinetics of Oxidation of Silicon Iron in an Air Atmosphere. V. V. Ipat'ev and G. M. Orlova. (*Zhur. Priklad. Khim.*, 1956, **29**, (6), 811–818). [In Russian]. The influence of small additions of silicon to iron on the velocity of oxidation in air of the alloy obtained and the influence of silicon on the structure of scale formed were investigated at temperatures 700, 800, 920, and 1000° C. It was found that the oxidation process takes place in an initial and a steady stage. Temperature dependence of the velocity constant for the steady stage was determined. 1·43% addition of silicon to iron sharply decreases the velocity of oxidation. The velocity constant of the oxidation process was correlated with the structure of the scale formed.—V. G.

Oxidation of Chromium–Silicon Steels in Air at High Temperatures. G. M. Orlova and V. V. Ipat'ev. (*Zhur. Priklad. Khim.*, 1956, **29**, (6), 819–828). [In Russian]. Kinetics of oxidation of 6% chromium steel containing 1·43, 1·86, and 3·34% of silicon in the temperature region 800–1200° were investigated. It was shown that in all cases the linear relationship between log K (velocity constant) and 1/T holds. Apparent energy of activation increases with increasing silicon content. Scale formed consists of three layers Fe_2O_3 external, Fe_3O_4 middle, and an internal spinel–fayalite layer $FeO.Cr_2O_3$ and $2FeO.SiO_2$ containing all the chromium and silicon.—V. G.

Some Aspects of Decarburisation. F. H. Robinson. (*Australasian Eng.*, 1956, **48**, Sept. 7, 42–51). Theories of the mechanism of decarburization are outlined, including kinetics, and medium carbon and tool steels considered in detail. Effects, structures, and tolerances are all discussed. A table of relative susceptibilities is added. (17 references).

On the Heat Treatment of Steel Castings. W. Hiller. (*Giesserei*, 1956, **43**, Nov. 22, 777–784). The iron–carbon equilibrium diagram is discussed together with the influence of alloying elements. A review is made of various types of steel usually used for casting and their textures. The annealing, normalizing, hardening, and tempering processes are discussed, with particular reference to the textures produced. The heat-treatment of highly alloyed steel castings is treated separately. The heating, soaking, and cooling processes are then considered from a physical viewpoint. Details and characteristics of various furnaces used for the heat treatment of steel castings are given.—R. J. W.

Effect of Heat Treatment on Distortion Caused by Heat Treatment of Cr–Mn–Mo Case-hardening Steel. K. Shinji et al. (*Tetsu to Hagane*, 1956, **42**, Sept., 875–878). [In Japanese]. Effects on hardness and mechanical properties are tabulated for a number of different treatments for first and second quenching between carburizing and tempering.—K. E. J.

Practical Aspects in the Heat Treatment of High-Alloy Tool Steels. C. J. Thompson. (*Australasian Eng.*, 1956, **48**, May 7, 50–55). The heat treatment of tool steels in which Cr, W, and Mo are the chief alloying elements is discussed. Precautions to be adopted with respect to carburization and decarburization are noted. The rapid heat-treatment cycle, nitriding, and steam tempering are also described.—A. W. McC.

Heat-treatment of Structural Steels for Improving their Properties. H. Staudinger. (*Härterei Tech. Mitt.*, 1956, **2**, Sept., 25–48). The author discusses heat-treatment as a means of surface hardening and in particular the influence of intrinsic stress after localized heat treatment. Cross-sectional area has to be taken into account. (22 references).—R. P.

Simplified Heat Treatment of Piston Pins in Rotating Retort Furnace. R. E. Haislip. (*Indust. Heating*, 1956, **23**, Nov., 2333–2334, 2336, 2338, 2340, 2342). Carburizing treatment for pins by the Chrysler Corp. is described in a furnace by Surface Combustion Corp.

Continuous Salt Bath Treatment Improves Farm Tools. (*Indust. Heating*, 1956, **23**, Nov., 2320–2322, 2324, 2326, 2328). The installation at Empire Plow Co. Ohio is described and illustrated. It is operated by one man.

Isothermal Heat-treatment of Agricultural Tynes. L. S. Heard. (*Australasian Eng.*, 1956, **48**, Oct. 8, 63–65). Chromium–zirconium steel was used and treatments, properties, variable hardness, and cracking were described and discussed in the light of the transformation diagram.

A Comparison of Single and Multiple Stack Annealing Furnaces. J. Arnold. (*Iron Steel Eng.*, 1956, **33**, Nov., 77–82). Advantages of single stack operation are discussed. Layout and economic factors are presented in some detail.

Annealing Malleable Iron. C. L. Ipsen. (*Foundry*, 1957, **85**, Jan., 104–109). Newer types of furnaces are reviewed and illustrated and their advantages given. Trends in foundry treatment, increase in pearlitic malleable, automation, and improved practice are considered.

Bell-Type Protective-Atmosphere Annealing Furnace for Sheet in the Upright Position. E. Labouvie. (*Stahl u. Eisen*, 1956, **76**, Dec. 27, 1741–1744). The author describes a bell-type furnace for 1-mm thick sheet 1 × 2 m for a throughput of 1·4 metric t/h. The protective atmosphere is produced by the combustion of town gas. The furnace has forced circulation, the sheets are separated from each other, which has the advantage of short heating-up times, even temperature distribution, and uniform cooling, thus improving quality, uniformity of structure, and mechanical strength. No sealing was observed for temperatures of 920° C (normalizing). Separation of the sheets reduces the throughput and involves higher costs of labour for loading and unloading.—T. G.

On the Bright Annealing of Special Steels. S. Yamada et al. (*Tetsu to Hagane*, 1956, **42**, Sept., 755–756). [In Japanese]. The use of converted propane is discussed, and the effects of nitrogen on the change in weight of 1% Cr steel annealed for 2 hours at 900° C in N_2–H_2 gas are considered; with 70% nitrogen, the weight change hardly varies with carbon content, but for nitrogen contents in the range 80–100%, it falls almost linearly with increase of carbon content up to 0·5%.—K. E. J.

Bright Annealing Plant. Extensions at Whitehead Iron and Steel Co. Ltd. (*Iron Steel*, 1957, **30**, Feb., 64). New vertical cylindrical furnaces are installed.

Continuous Annealing of Steel Plate Strip. H. Drever. (*Iron Steel Eng.*, 1956, **33**, Oct., 109–110). A brief review of tinplate installations.

On the Isothermal Annealing of High Carbon Steel. H. Takei. (*Nippon Kinzoku Gakkai-Si*, 1953, **17**, Dec., 639–642). [In Japanese]. For annealing file steel containing 1·5% C from Rockwell hardness 46–48 to 20–23, the optimum temperature was found to be 800–850° C for 1 h, followed by holding at 650–700° C for 1–1·5 h.—K. E. J.

Annealing Motor Laminations. (*Process Control Automation*, 1956, **3**, Oct., 363–364; *Beama J.*, 1957, **64**, Feb., 39). The furnace, process, temperature cycle, and furnace atmosphere used by Messrs. Hoover Ltd., Cambuslang, is described. The furnace is of roller hearth type made by Birlec Ltd.

Low Temperature Annealing of Drawn Wire. K. Nakamura and Y. Nakamura. (*J. Mech. Lab.*, 1956, **10**, Sept., 195–201). The hardening effect of drawing on 0·64% and 0·84% C steel wire was studied measuring rise in temperature. After patenting, drawing to total reductions of 30% and 60% was carried out and annealing conditions investigated. Tensile strength and hardening showed an inverse relationship.

Changes of Anisotropy Resulting from Annealing of Mild Steel. Y. Hosoi et al. (*Tetsu to Hagane*, 1956, **42**, Sept., 886–887). [In Japanese]. Armco, killed, and rimmed steels (analyses given) were tested. The data show the changes in the relationship between magnetic torque and the angle from the rolling direction produced by various annealing treatments.—K. E. J.

The Manufacture of a Large Reaction Vessel in Ni–Cr–Mo Steel. E. de Kerversau, A. Pierre, and P. Lamotte. (*Iron Steel Inst. Spec. Rep.*, **60**, 1957, 53–59). Experience at Le Creusot works and the development of antiflake treatment is described. Choice of steel, forging, and swaging with overall heating and finishing with partial heats are outlined and precautions and antiflake treatment by cooling are discussed. The development of the treatment since 1949 is described and hydrogen removal considered.

Fundamental Research on Heat-Treatment of Isothermal Transformation. I. Dilatometric Study on Relationship between Martempering and Time-quenching. Y. Mitani. (*Nippon Kinzoku Gakkai-Si*, 1954, **18**, July, 409–413). [In Japanese]. The first stage of shrinkage of quenched high-carbon steels (100–150° C) is considerably reduced with martempered steels, much tempered martensite being found in the microstructure; the second stage, however, is almost unchanged. The reduction of the shrinkage is attributed to tempered martensite or lower bainite, reducing the quenching strain.—K. E. J.

Fundamental Research on Heat-Treatment of Isothermal Transformation. II. Dilatometric Study on Determination of M_S, and its Examination. Y. Mitani and N. Nakanishi. (*Nippon Kinzoku Gakkai-Si*, 1954, **18**, July, 413–417). [In Japanese]. By using a dilatometer with a 4000-fold degree of magnification of the scale reading, the M_S point can be determined within ± 1° C. Retained austenite does not affect the method.—K. E. J.

Changes in the Properties of Steel Caused by Stress-Ageing Treatment. II. On the Effects of Ageing Temperature and Ageing Time. T. Sakurai, T. Kawasaki, and H. Izumi. (*Nippon Kinzoku Gakkai-Si*, 1955, **19**, Dec., 711–715). [In Japanese]. Stress-ageing of mild steel increases the hardness, the higher the temperature of treatment the shorter the time needed for the hardness to reach its maximum. The greatest rate of increase of hardness and the highest strength are obtained by short treatment at a temperature just below its recrystallization temperature. The higher the ageing temperature and the longer the time, the lower the residual stress. Correct choice of temperature and time will ensure increased strength and hardness and decreased residual stress, with no change in ductility.—K. E. J.

Normalisation of Grey Cast Iron and Rational Choice of a Type of Cast Iron Conforming with Requirements in Use. A. De Sy. (*Reprint*, pp. 10). Tensile specimens are discussed and a classification is proposed as a function of strength and specimen dimensions. A correlation equation for properties after normalization is given and suggestions for standardization between foundries are made.

On the Austempering Process of Si–Mn Spring Steel. H. Takahashi. (*Tetsu to Hagane*, 1956, **42**, Sept., 887–888). [In Japanese]. Cooling velocities produced by oil at 25–35° C and 100–120° C are compared. Data are shown for mechanical properties of quenched and tempered steel, and of austempered steel, and their variation with quenching time.—K. E. J.

Today's Quenching Needs. S. J. Barber. (*Metal Treating*, 1957, **8**, Jan.-Feb., 2–6, 28). Water and oil quenching are discussed. Requirements for quenching oils and the use of mineral oils are reviewed. Oil cooling and interrupted quenching are referred to and a set of general hints are added.

The Temperature of Quenching Media and Retained Austenite. R. Tanaka et al. (*Tetsu to Hagane*, 1956, **42**, Sept., 889–890). [In Japanese]. For specimens quenched by water or oil, and cooled in ice-water or air, the effect of the temperature of the quenching medium (0–240° C) on the amount of retained austenite in eutectoid carbon steel is shown. The effect of holding time (5 s–1 day) in quenching oils at 60° C and 120° C on retained austenite is also shown.—K. E. J.

Hot-bath Quenching at Low Temperature Range of High-C, Low-Cr, Low-W Steel. II. On the Deformation in Quenching and Ageing, and Toughness. I. Tatsukawa. (*Tetsu to Hagane*, 1956, **42**, Sept., 890–892). [In Japanese]. For specimens quenched at 150° C for periods between 2 and 40 h, the dimensional changes in ageing (up to 300 h) at room temperature are shown. Relationships between dimensional changes, intensity of magnetization, hardness, absorbed energy, and heat treatment are illustrated.—K. E. J.

Rockets for Steel Hardening. J. A. Browning. (*Welding J.*, 1957, **36**, March, 225–229). Small rockets fuelled by oxygen and propane have been investigated for flame hardening of steel. Progressive linear hardening at 35 ipm of flat specimens of 4150 steel produced maximum Rockwell hardness of C68 with a case depth of $\frac{3}{64}$ in. The extremely fast heating rates followed by water quench produced hardness values higher than those obtained by conventional heating techniques.

Continuous Hardening and Tempering of Steel Strip. (*Indust. Gas*, 1957, **20**, Mar., 22–24). Gas heated equipment designed by Messrs. G. F. Homer (Redditch) Ltd. is described. The strip passes at 3·5–25 ft/min.

Flame Hardening. (*Torch*, 1957, Spring, 2–7). An illustrated review.

Induction Hardening of Automobile Rear Axles. P. Woodie. (*Indust. Heating*, 1957, **24**, Apr., 718, 720, 722, 724, 726).

New Nitriding Process Uses Glow Discharge. P. M. Unterweiser. (*Iron Age*, 1957, **179**, May 2, 91–93). A brief account of the process with illustrations of apparatus and structures produced.

Sulfurizing—New Surface Treatment—Reduces Scoring and Seizing. G. B. Troup. (*Mat. Methods*, 1956, **44**, Sept., 110–113). The salt bath process developed in France is outlined. Load-torque and wear curves are given.

Sulphidizing of Chromium Stainless Steels. E. P. Pukhovskii, P. A. Sakharova, N. A. Shigunova, and G. P. Budaev. (*Metallovedenie i Obrabotka Metallov*, 1956, **2**, (5), 40–43). Trial procedures on test pieces using FeS–graphite–$K_4Fe(CN)_6$

mixtures are described, and wear tests against steel discs were carried out. Work is continuing.

Applications of Furnace Atmospheres. C. E. Peck. (*Metal Progress*, 1957, **71**, Mar., 104–112). The properties of a range of controlled gas atmospheres used in heat-treatment furnaces are described. The selection of a gas composition for the annealing of a variety of irons and steels is discussed in detail. Carburizing and carbonitriding are also considered.—B. G. B.

How to Heat Treat Gray Iron. C. R. Austin. (*Mod. Castings*, 1955, **28**, Nov., 30–33). Annealing for stress relief, heating and quenching for full hardness, heating, quenching, and drawing to increase strength and toughness and surface or local hardening are discussed. The theory of heat treatment, conventional and interrupted quench treatments and other processes are briefly outlined.

Versatile Furnace for Continuous Annealing of Stainless Wire at Carpenter Webb Wire Plant. (*Indust. Heating*, 1957, **24**, Jan., 87–90). A gas fired furnace capable of handling a wide range of wire sizes is described.—A. D. H.

Continuous Annealing Lines for Tinplate—Recent Trends and Problems. J. H. Hopper and A. Jakimovich. (*Iron Steel Eng.*, 1957, **34**, April, 80–86). The authors discuss the advantages of continuous annealing lines for tinplate. They claim a more uniform product, a higher strength, better corrosion resistance. Direct costs are higher than for box annealing. Details are given of the plant, the furnaces, and of the electrical drives and controls. (7 references).—M. D. J. B.

Electrical Equipment for Continuous Annealing of Silicon Steel Strip. G. J. Hay and H. S. Fegely. (*Iron Steel Eng.*, 1957, **34**, March, 78–84). The article describes recently installed facilities for the continuous annealing of silicon steel strip in a Pittsburgh steel plant designed to handle strip widths of 18 to 42 in. in thicknesses of 0·007 to 0·031 in. The plant has a capacity of 20 tons per hour.—M. D. J. B.

Automatic Anneal Ups Output 800%, Nets ¾ c per Lb. Savings, On Silicon Steel Laminations. (*Western Metals*, 1957, **15**, Feb., 44–46). An illustrated account of a three-section Lindberg unit fed by 5 high speed presses is given.

Mill Requirements Point to Five-Zone Furnace. J. E. Hovis. (*Iron Steel Eng.*, 1957, **34**, April, 98–102). This paper reviews heating requirements as dictated by present mill practice. Details are given of re-heating furnaces for structural mills, plate mills and strip mills.—M. D. J. B.

Dimensional Changes due to Annealing of Plastically Cold-worked Metals. III. On Dimensional Changes due to Annealing of Low-carbon Steel Rods or Plates Drawn, Rolled or Bent. H. Sekiguchi and M. Inagaki. (*Nippon Kinzoku Gakkai-Si*, 1955, **19**, Mar., 220–223). [In Japanese]. Drawn, rolled or bent specimens as well as elongated or compressed ones exhibited dimensional changes due to low-temperature annealing in the same direction as the deformation due to working before annealing. The fundamental origin of this is not thought to be residual macrostresses.—K. E. J.

Slack Quenching of Steels. D. J. Blickwede and R. C. Hess. (*Metal Progress*, 1957, **71**, Mar., 97–103). Quenching diagrams are presented for several common engineering alloy steels which enable the metallurgist to predict the course of transformation and the eventual microstructures and hardnesses of various sized parts quenched either in oil or water.—B. G. B.

Choosing the Right Quench. O. E. Cullen. (*Steel*, 1957, **140**, May 13, 123–126). A review of austempering, martempering, marquenching and other treatments, of additives, quench tank design, distortion effects and notes on possible developments is given.

On Changes of Hardness and Magnetic Properties of Mild Steel due to Quenching. T. Kawasaki, G. Shinoda, and Y. Kita. (*Nippon Kinzoku Gakkai-Si*, 1954, **18**, Oct., 535–539). [In Japanese]. On quenching of 0·18% C steel, hardening occurs by thermal stress, producing slip at the outer layers; softening occurs simultaneously. With low-temperature quenching (100–250° C), hardening and softening are just balanced; at temperatures above 400° C there is considerable hardening. With commercially pure nickel, the hardness change mainly depends on thermal stress. The slope of the magnetization curve is decreased by quenching, but when tension is applied at a temperature below the recrystallization temperature, all specimens show the same magnetization curve; this result, however, is not obtained above 450° C. (11 references).

Study on Strain Tempering. IV. Effects of Strain Tempering on Mechanical Properties of Various Carbon Steel Wires. M. Jingozaemon. (*Nippon Kinzoku Gakkai-Si*, 1954, **18**, Nov., 561–565). [In Japanese]. The "KRK" strain tempering process improves the mechanical properties of low-carbon steel wires as well as those containing 0·6–0·9% C. Strength increases as carbon content and reduction are increased; the maximum strength increase depends on a combination of carbon content, reduction and treating temperature.—K. E. J.

FORGING, STAMPING, DRAWING, AND PRESSING

Twenty-Five Years Progress in the Forging Industry. (*Australian Mach. Prod. Eng.*, 1957, **10**, Feb., 48–50, 66). An account is given of the growth of Australian Forge and Engineering Pty., Ltd. Typical products are shown.

Development Problems in the German Drop-Forging Industry. Difficulties of Automation. O. Niederhoff and F. D. Schieferdecker. (*Metal Treatment and Drop Forging*, 1957, **24**, May, 187–197). The nature of automation and its applications in machining and comparisons with drop forging are discussed. Developments in drop forging are then reviewed with special reference to the energy consumed, heating methods, and possible improvements.

Guide for Forging Stainless. W. E. McFee. (*Steel*, 1957, **140**, Apr. 15, 150–152). Recommended temperatures, soaking times and cooling methods for Cr–Ni, martensitic and ferritic Cr steel forgings are given.

Making of Forging Dies by Means of Hot Pressing of the Die Shape. T. Kalán. (*Kohászati Lapok*, 1954, **9**, Sept., 390–399). The making of forging dies by means of hot pressing of the die shape and the subsequent heat treatment are discussed in detail.—P. K.

Large Rotor Forgings for Turbines and Generators. N. L. Mochel, R. E. Peterson, J. D. Conrad, and D. W. Gunther. (*Trans. Amer. Soc. Mech. Eng.*, 1956, **78**, Oct., 1585–1601). A brief history is given of the development of present designs, materials used, manufacturing methods, and the testing practices employed.—D. H.

Work of the Task Group on Brittle Failure of Steel Forgings. A. O. Schaefer. (*Trans. Amer. Soc. Mech. Eng.*, 1956, **78**, Oct., 1623–1626). The author surveys briefly the work of Sub-Committee VI Task Force on brittle failure of steel forgings, a division of Committee A-1 of the ASTM.—D. H.

Small Shear Replaces Dies On Short Runs. T. M. Rohan. (*Iron Age*, 1957, **179**, Mar. 7, 136–137). A 24-in. shear has been designed to take the place of blanking dies in the preparation of small lots of straight-sided parts. The machines work at 120 strokes per min and can be linked together in an automatic line for working with coiled strip.—G. F.

Heavy Presses: Strain Gages Stand Guard. L. Mollick and J. Jursik. (*Steel*, 1957, **140**, Jan. 28, 92–93). The authors outline the need for corrective systems to offset eccentric loading in heavy presses, and give brief details of a system consisting of automatic hydraulic compensation with strain-gauge controls operating when the automatic system is at its maximum capacity.—G. F.

The Use of Plasticine as an Analogy for the Hot Working of Steel. R. Green. (*Rail. Steel Topics*, 1956, **3**, Autumn, 41–50). Internal flow in forging and rolling is studied with laminated plasticine models. Comparison with steel is made.

Automation in the Press Shop. E. E. Michaelis. (*Automation Prog.*, 1957, **2**, June, 282–285). An illustrated review of press tool work.

New Shapes from Old Rails. W. H. Jacobs. (*Mat. Methods*, 1956, **44**, Aug., 114–115). Uses of rails withdrawn from service are outlined.

Ductile Spring Steel Withstands Severe Forming. (*Iron Age*, 1956, **178**, Dec. 20, 90). High-carbon spring steel, used by Thompson Products Inc., St. Louis, to produce flexible all-steel oil-control piston rings, withstands severe cold forming and yet, after heat treatment, possesses great elasticity. The properties of the steel are discussed.—G. F.

Setting of Coil Springs. U. Otzen. (*Draht, German ed.*, 1957, **8**, Feb., 49–54). The setting of coil springs is analysed, with reference to investigations by the author in which the effects of residual stresses, heat treatment, and geometrical factors were measured.—J. G. W.

Cast Steel Shot Abrasive. (*Machinery Lloyd*, 1957, **29**, Jan. 26, 53). Its advantages over chilled iron shot are mentioned.

On Shot for Peening. V. Effect of Shot on the Archeight, Coverage and Roughness. M. Uchiyama et al. (*Tetsu to*

Hagane, 1956, **42**, Sept., 729–731). [In Japanese]. Results are given for residual compressive stress, depth of peened layer, curvature, coverage, and surface roughness produced when shot of seven degrees of hardness between 162 and 726 Vickers is used on specimens of eight degrees of hardness between 177 and 705 Vickers. The effects of degree of roundness of the shot are also discussed.—K. E. J.

A Fundamental Study of the Application of Shot Peening to Bright Hoop. T. Nakao et al. (*Tetsu to Hagane*, 1956, **42**, Sept., 731–732). [In Japanese]. Stress-strain curves are given for rimmed steel artificially aged for periods between 1 min and 2 h, and for steel sand-blasted under loads between 4·5 and 6·5 kg/cm² for periods between 5 and 20 s.—K. E. J.

Advances in the Field of Cold-Forming in Germany and the U.S.A. K. Sieber. (*Draht, English Ed.*, Dec., 15–20). Applications of cold-forming techniques to parts formerly machined are described.

The Metallurgy of Steels for Deep Drawing. A. J. K. Honeyman. (*Sheet Metal Ind.*, 1957, **34**, Jan., 51–65). Analyses, structures, ingot characteristics, mechanical properties of hot-rolled sheets, and of cold-reduced sheets, and their measurement are all discussed, with a review of theories of yielding and ageing. Assessment of deep-drawing properties is then considered in some detail.

Analysis of Metal Deformation During the Drawing Process. M. Lanfranco. (*Ingegneria Mecc.*, 1956, **5**, Dec., 33–42). [In Italian]. Deformations and stresses are studied in plastic cold working of metals and examined in the context of the elastic and plastic theories. The author shows how the results of his investigation can be applied to metal drawing. Metal drawing parameters are given and drawing forces and stresses are evaluated as well as friction coefficients. (14 references).

On the Mechanism of the Action of Lubricants in the Forming of Metals. S. Ya. Veiler, V. I. Likhman, and P. Rebinder. (*Doklady Akad. Nauk S.S.S.R.*, 1956, **110**, (6), 985–988). [In Russian]. This is a study of the role of lubricants in the working of metals by compression or drawing, and as affecting their plasticity and flow. Experiments were carried out on iron and brass wires.—S. I. T.

Manufacture of Drawn Valve Rods. (SEH3). S. Yoshimura et al. (*Tetsu to Hagane*, 1956, **42**, Sept., 926–928). [In Japanese].—K. E. J.

Temperature Measurement During the Drawing of Steel Wire.—I. W. Lueg and K.-H. Treptow. (*Stahl u. Eisen*, 1956, **76**, Dec. 13, 1690–1698). The authors review published work on the various methods used in temperature measurement of wire during drawing and report their own investigations. They used three methods: (*a*) the wire/die thermocouple; (*b*) the split-die thermocouple; and (*c*) the Zastera clamp incorporating a conventional thermocouple. The presence of a lubricant on the wire had no effect on the results obtained in (*a*) and (*b*). Method (*a*) gives results of good reproducibility and reflects truly the various effects in the drawing operation, it can be used at all drawing speeds, (*b*) has the advantage that calibration of the temperature is independent of the nature of the wire and is therefore particularly suitable for exact laboratory investigations, but not for operational control as special dies are used which are not suitable for commercial production. The temperature shown in (*c*) is affected by the drawing speed, wire diameter, etc. Method (*c*) is not suitable for accurate temperature measurement.—T. G.

Colloidal Graphite does Excellent Job as Wiredrawing Lubricant. (*Iron Steel Eng.*, 1956, **33**, Nov., 140, 143, 145). Mild steel wire drawing lubricants are compared.

The Effect of an Active Lubricating Medium on the Process of Wire Drawing. V. D. Chistota, S. Ya. Veiler, V. I. Likhman, and P. A. Rebinder. (*Doklady Akad. Nauk S.S.S.R.*, 1956, **110**, (4), 562–565). [In Russian]. The effect of various lubricants on the process of iron wire drawing was studied. It was found that in the case of organic lubricants their effect was largely dependent on the number of carbon atoms in the molecule, but other factors are also discussed.—S. I. T.

Selection of a Lubricant for Cold Drawing. I. Coarse Steel Wire. B. W. Siemon. **II. Fine Steel Wire.** W. B. Bauzenberger. (*Iron Steel Eng.*, 1956, **33**, Nov., 105–108). A discussion in general terms of the purpose of the lubricant and the kinds of mixtures used.

Appraisal of Rolling Oil Emulsions by Wire Drawing Tests. W. Lueg and W. Dahl. (*Stahl u. Eisen*, 1956, **76**, Dec. 13, 1669–1671). The authors attempt to find a wire drawing test for the appraisal of rolling oil emulsions by measuring the drawing force of steel wire of various U.T.S. The tests are described in detail but show no relationship between suitability of an emulsion in the rolling mill and the drawing force of steel wire. The authors attribute this to: (i) the speed in wire drawing being very much higher than in rolling, i.e. the time in which a surface-active lubricant can affect the drawing process being very short; (ii) the behaviour of the cemented carbides, used for drawing dies, with lubricants being still unknown; (iii) the introduction of the lubricant into the die cavity being entirely different from that in rolling; and (iv) the relative movement of work roll to work piece being small, whereas in wire drawing they are very high.—T. G.

The Drawing of Steel with Glass Lubricant. T. Sejournet. (*Mem. Soc. Civils France*, 1956, **109**, Sept.-Oct., 361–379). A comprehensive account of the Ugine–Sejournet Extrusion process is given. Factors influencing extrusion are explained and the type of presses in use are described. Examples of the type of extrusion possible are shown.—B. G. B.

Effect of Straightening and Tempering on the Elastic Properties of Steel Wire. W. Püngel. (*Stahl u. Eisen*, 1956, **76**, Dec. 13, 1685–1689). Samples of steel wire, diameter *d*, for mechanical testing are taken from the coils and prepared by straightening with a mallet and tempering at various temperatures. Straightening and tempering at 200° C markedly affect elongation at the elastic limit. Elongation at fracture is affected when the wire is tempered above 450° C. Straightening after tempering, however, reduces elongation at the elastic limit. The diameter of the coil from which the specimen is taken materially affects the elongation values of the test pieces, the best diameter is 500–600*d*. Prestraining of the wire increases the elongation at proof stress to such an extent that the values of the tempered wire are obtained. This is commercially used in the fabrication of wire for use in prestressed concrete.—T. G.

Surface Defects on Drawn Steel Wire. C. James. (*J. Australian Inst. Met.*, 1956, **I**, May, 40–48). Surface defects are traced from rod to finished wire and examples of service failures are included. Fins, ovality, cross rolling, laps, slivers, seams, decarburization, and pits in rod are considered and poor lubrication effects, scratches, seizure, and weld defect in wire drawing. Effects on fabrication and use are then illustrated.

Welded Wire Mesh. Office of Technical Services, Washington. (*IR–16195–EP*; TIDU List 681, 1956, pp. 1). A welding data chart prepared by Taylor–Winfield Corp. tabulating optimum time–force–current conditions. Mild steel, 18–8 stainless, and Monel can be used.

Costing—A Tool of Wire Mill Management. E. Copley. (*Prize Paper in Frederick Smith and Co. Staff School Open Awards* 1955, pp. 11). An exhaustive account of a wire mill costing system.

Cold Extrusion of Steel. W. de Lima e Silva. (*Eng. Min. e Met.*, 1956, **24**, Oct., 203–206). [In Portuguese]. A general review of these processes is given, and suitable steels for extrusion and for the dies and tools are discussed together with methods of lubrication and the types of presses required.

A New Method of Cold Extrusion. M. Kunogi. (*J. Sci. Res. Inst.*, 1956, **50**, Dec., 215–246). Backward extrusion of low-carbon steel is performed using new types of dynamometers and displacement-measuring devices. Tool shape is discussed and optimum ratios given and friction tests described on various lubricants. The method can be used for stainless and case-hardening and nitriding steels. Cemented carbide punches are used.

Application of Type CBJ Hydraulic Presses (in) Cold Extrusion of Steel. O. Štěpánek. (*Czech. Heavy Ind.*, 1956, (5), 31–37). The presses and tools, their operation and lubrication are described in an account illustrated with 15 diagrams.

Studies on Cold Extrusion of Steel. III. Influences of Lubricants on the Extrusion Force. S. Tsujimoto et al. (*Tetsu to Hagane*, 1956, **42**, Sept., 825–826). [In Japanese]. The influence of Bonderite in various amounts for a steel of given composition is shown in curves of extrusion force against distance. The influence of extrusion speed on force is shown for room temp., 100° and 200° C.—K. E. J.

Studies on Cold Extrusion of Steel. IV. On Extrusion Force, Frictional Force and Tangential Stress of Dies. S. Tsujimoto et al. (*Tetsu to Hagane*, 1956, **42**, Sept., 826–827). [In Japanese]. Curves of stress and extrusion force against strain are given for several specimens. The influences of initial and final dimensions on drawing force, frictional coeff. and extrusion force are considered.—K. E. J.

Hot Extrusion of Carbon Steel Solid Sections. J. K. Seyler. (*Iron Steel Eng.*, 1956, **33**, Dec., 89–91). The present state of development of the process and the kind of product it manufactures are reviewed.

Draw, Polish Bar in One Machine. J. H. Glose. (*Iron Age*, 1957, **179**, Feb. 28, 88–89). Details are given of the "Schumag" machine, made by Schumacher Metallwerke A.G., which cold draws, cuts to length, straightens, and highly polishes steel bars from coiled rods. The bars are perfectly straight and more highly concentric, and are produced in lengths up to 24 ft in round, square, hexagon, or flat sections from $\frac{7}{16}$–$\frac{1}{2}$ in.—G. F.

Warm Drawing Improves Fatigue Life. (*Steel*, 1957, **140**, Jan. 28, 94–95). By elevated temperature (600–1200° F) drawing with careful control of both deformation and temperature, La Salle Steel Co. (Indiana) produces a carbon steel with the properties of alloy steels. The steel is 0·45% C, 1·5% Mn, and its important properties are fatigue-resistance and toughness without heat treatment.—G. F.

Tube-Forming. (*Aircraft Prod.*, 1957, **19**, May, 174–179). An account is given of airscrew blade core-tubes production by de Havillands. The tubes are cold-drawn in 10 stages with annealing in sealed N_2-purged pots.

Studies on Impact Extrusion. IX. On Cold Impact Extrusion of Steel. I. Gokyu, H. Suzuki, and T. Tada. (*Nippon Kinzoku Gakkai-Si*, 1955, **19**, Oct., 575–577). [In Japanese]. In cold backward impact extrusion of 0·10% carbon steel, lanolin and wax proved to be the best lubricants applied to a zinc phosphate coating. With these, the limit of extrusion reduction was approx. 50–60% in 20-mm shells, the specific extrusion force being 250 kg/mm² or a little higher. The curves of extrusion force resembled those of non-ferrous metals. Some physical properties of the shells are given. (12 references).—K. E. J.

ROLLING-MILL PRACTICE

Let Magnets Clean Up Rolling Mill Coolants. A. L. Wilson jun. (*Iron Age*, 1957, **179**, Mar. 7, 132–133; *Brit. Steelmaker*, 1957, **23**, May, 146–148). Magnetic separators are proving very effective in removing contaminants from rolling mill coolants, thereby reducing costs. Typical installations are briefly described and the level of efficiency is indicated.—G. F.

Position Control of Screwdown. (*BISRA Summary*, 100, 1957, pp. 2). Position control, its uses, advantages and application, with the three methods using limit switches, potential dividers and synchro elements, with an account of the BISRA remote control scheme are briefly outlined.

The Multi-row Cylindrical Roller Bearing Roll Neck Mounting. E. C. Denne jun. (*Iron Steel Eng.*, 1957, **34**, March, 110–120). The article discusses multi-row roller bearings for mill mountings; their performance, maintenance and lubrication are described in some detail and their advantages are discussed.—M. D. J. B.

The New 10 in. Bar Mill—Jones & Laughlin Steel Corp. H. I. Smith. (*Iron Steel Eng.*, 1957, **34**, April, 75–78). This article describes a new 16-stand continuous repeater 10-in. bar mill capable of rolling 30,000 t monthly in sizes ranging from 19/64 to 1¼ in. rounds starting from 2½ or 3 in. billets.

New Rod Mill at Bethlehem's Johnstown Plant. J. C. Seibert. (*Iron Steel Eng.*, 1957, **34**, March, 71–77). The author describes the 23-stand rod mill at the Johnstown works of the Bethlehem Steel Co. which is a complete modern high-speed mill designed for rolling rod coils in sizes $\frac{5}{32}$ to $\frac{3}{4}$ in. diam. Details are given of the excavations, foundations and construction, of the electrical equipment, lubricating systems, billet charging, mill stands and mill operation.—M. D. J. B.

Electric Equipment for Atlantic Steel Company's Merchant Bar and Rod Mill. F. E. Fairman. (*Blast Furn. Steel Plant*, 1957, **45**, Feb., 193–199). The electric drives for this modern mill which has a delivery speed of 5000 ft/min for rods and 2000 ft/min for merchant products are described.—B. G. B.

Brinsworth Mill. (*Rail. Steel Topics*, 1957, **4**, Spring, 4–10). An illustrated description.

The Application of Spiral-Rolled Drill Steel in Canada. T. W. Wlodek. (*Canad. Min. Met. Bull.*, 1957, **50**, Apr., 208–211). (22 references).

Reducing Smudge on Cold Rolled Sheet. M. A. Matz. (*Iron Steel Eng.*, 1957, **34**, April, 105–106). Certain factors essential to the production of good cold rolled sheet are briefly discussed. The importance of careful hot rolling, pickling, and annealing is stressed.—M. D. J. B.

New Semi-Continuous Hot-Strip Mill in Belgium. Installation at S. A. Cockerill-Ougrée (Seraing). (*Iron Coal Trades Rev.*, 1957, **174**, Mar. 22, 673–674, 672). The 6-stand 4-high 68-in. hot-strip mill producing coils up to 10 t of steel down to 0·0495 in. thick is described.

Nucleonic Thickness Gauge for Hot Steel Strip. (*Process Control Automation*, 1957, **4**, May, 162–165). A detailed account of the gauge fitted by Steel, Peech and Tozer on a Morgan strip mill.

A New Insulation for Auxiliary Mill Motors. M. W. Kitzmiller. (*Yearly Proc. Assoc. Iron Steel Eng.*, 1956, 741–743). Testing methods are described.

The "600" Series Mill Motor. (*Electr. Eng. Merchandiser*, 1957, **33**, Feb. 20, 342–343).

MACHINERY FOR IRON AND STEEL PLANT

Scrap Balers: Put Your Money Where It Counts Most. J. E. Hyler. (*Iron Age*, 1956, **178**, Dec. 20, 80–82). The author gives brief details of some of the varieties of scrap-baling equipment now available, and discusses the important points to be considered in choosing the equipment.—G. F.

Ladle Cranes Reach 500-Ton Size. (*Iron Steel Eng.*, 1957, **34**, March, 145–149). The article describes a 500-ton ladle crane which will be capable of lifting a ladle holding 375 tons of hot metal. Details are given of the crane bridge, crab and crane cab.—M. D. K. B.

Maintenance of Weighing Scales. G. E. Evans. (*Iron Steel Eng.*, 1957, **34**, March, 86–91). Various types of scales in use at The Sparrows Point works of Bethlehem Steel Co. are described in some detail. The article is fully illustrated.

First Cost versus Maintenance Cost for Electrical Overhead Traveling Cranes. W. A. Perry. (*Yearly Proc. Assoc. Iron Steel Eng.*, 1956, 318–323). A review is given of the development of the steel mill crane and an outline of desirable features. Relatively little is included about costs and no actual figures are given.

Ideal Maintenance Machine Shop Facilities. W. J. Pearson. (*Yearly Proc. Assoc. Iron Steel Eng.*, 1956, 708–713). A review of modern machines and equipment.

Protection of Men Exposed to the Hazards of Moving Overhead Electric Cranes. H. R. Miller. (*Iron Steel Eng.*, 1957, **34**, March, 122–124). The author describes procedures at Armco's Butler plant to reduce accidents on crane runways.—M. D. J. B.

LUBRICATION

Steelworks Lubrication: Methods and Practices in Germany. H. P. Jost. (*Iron Steel*, 1957, **30**, Apr., 137–138). The author reports on the visit of a party of British technicians to a number of German steelworks to discuss lubrication problems. The German methods and practices are outlined. In general, reliable lubrication of the simplest nature is demanded, with a preference for direct line grease lubrication equipment.—G. F.

The Mechanics of Lubrication. C. L. Pope. (*Yearly Proc. Assoc. Iron Steel Eng.*, 1956, 755–757). A review of dry, boundary, and fluid film lubrication.

Bearings, Lubricants and Lubrication. (*Mech. Eng.*, 1956, **78**, Aug., 703–714). A digest of the 1955 literature. (208 references).—D. H.

Molybdenum Disulphide as an Aid to the Lubrication of Difficult Conveyors. H. P. Jost. (*Metal Finishing J.*, 1957, **3**, Mar., 99–102). Use in conjunction with pickling tanks is described.

Hydroxyarylstearic Acids as Oxidation and Rust Inhibitors in Lubricants. H. Gisser, J. Messina, and J. Snead. (*Indust. Eng. Chem.*, 1956, **48**, Nov., 2001–2004). Preparation from phenols and stearic acid and anticorrosion tests are described. Hydroxyphenylstearic was the most effective.

WELDING AND FLAME-CUTTING

Fire Welding. E. Blechynden. (*New Zealand Eng.*, 1957, **12**, Jan. 15, 33–37). A review of the welding of iron and steel by the old smiths' methods.

How New is the Welding Process? H. J. Nichols. (*Canad. Metals*, 1956, **19**, Dec., 30–32). A short review is presented of the development of the welding process from prior to 1914 to the present day.—B. G. B.

Metal Arc Welding of Mild Steel Plate. R. S. Bolton. (*New Zealand Eng.*, 1956, **11**, Dec., 400–408). A review of processes, defects, stresses, inspection, and other topics is given. (21 references).

Some Aspects of Welding Structural Steel. W. Burrows. (*New Zealand Eng.*, 1956, **11**, Dec., 415–418). Work on the Wairau bridge is described. Welding procedure, choice of electrodes, tests for operators and inspection are briefly discussed.

A Japanese Process for CO_2-Shielded Arc Welding of Steel. H. Sekiguchi and I. Masumoto. (*Brit. Welding J.*, 1957, **4**, May, 205–212). Bare wire electrodes containing deoxidants are used. Welding tests are reported showing good mechanical properties and very low H_2 content of weld metal. Joints and fracture surfaces are illustrated.

Austenitic Welds in Type 502 Steel Piping. H. G. Geerlings and W. P. Kerkhof. (*Welding J.*, 1957, **36**, March, 119s). An abstract of a paper which was published in Lastechniek, **22**, 176–181, Nov. 1956. It is shown that in field welding austenitic electrodes are better than type 502 electrodes. Where heat treatment is possible type 502 electrodes are preferred.—U. E.

Welding of High-Strength Pressure-Vessel Steels in Heavy Sections. A. P. Bunk. (*Welding J.*, 1957, **36**, Feb., 62s–66s). An investigation is reported on the determination of adequacy of welding procedures in meeting ASME Code requirements when 4-in thick carbon and low-alloy steels are joined by the manual metal-arc process.—U. E.

Study of Interrupted Welding of Heavy-wall Steam Pipe. I. A. Rohrig, J. O. Smith, and E. G. Shifrin. (*Welding J.*, 1957, **36**, Feb., 128–131). It is shown that a 2¼% Cr, 1% Mo alloy steel pipe of ¾ in. thickness can be successfully welded with interrupted heat cycles, provided precautions are taken.

Joint Design for Making Root-Pass Welds Without Filler Metal. L. C. Lemon and W. R. Smith. (*Welding J.*, 1957, **36**, March, 240–242). A detailed description is given of joint design and welding technique employed to produce root pass welds without the use of backing rings.—U. E.

Peripheral Welding of Internally-Clad Steel for Nuclear Reactor Application. W. Leonard and J. C. Thompson jun. (*Welding J.*, 1957, **36**, March, 243–251). A description is given of welding 4 in. carbon steel clad with a 10% thickness of type 347 stainless steel on the interior used for pressure vessel shells. Chemical and mechanical properties of the steel are given. Photomicrographs show the constitution of the joint.—U. E.

Rating System Simplifies Welding Electrode Selection. O. T. Barnett. (*Iron Age*, 1957, **179**, Apr. 4, 91–96). Almost all requirements for the manual arc welding of mild steel are covered by nine coated electrode specifications, each having advantages and disadvantages under specific conditions. To assist in electrode selection, a table is presented in which all welding variables are considered and each electrode type given a rating.—G. F.

Iron Powder Electrode Effectively Used in Fabricating Turnpike Expansion Joints. R. Hall. (*Welding J.*, 1957, **36**, March, 264). A brief note on the welding method employed with the Ohio Turnpike bridge and using iron-powder type electrodes.—U. E.

A Comparative Study of Thoriated, Zirconiated and Pure Tungsten Electrodes. L. P. Winsor and R. R. Turk. (*Welding J.*, **36**, March, 113s–119s). It was found that thoriated-tungsten electrodes showed superior starting performance during d.c. straight polarity welding of stainless steel, followed by zirconiated tungsten and pure tungsten. Metallographic studies of the electrodes showed that erratic arcing and the rate of erosion are both functions of the type of recrystallized structure existing in the electrode tip during welding.—U. E.

Effect of Irradiation on Weldability of ASTM. A212. Grade B. W. R. Hutchinson. (*Welding J.*, 1957, **36**, March, 105s–112s). Weldability tests were carried out on ASTM A212, Grade B pressure vessel plate in both irradiated and unirradiated conditions. An integrated thermal neutron flux in excess of that anticipated at the time of re-welding of Mark I pressure vessel was chosen. No difficulties were observed nor any harmful effects noted during subsequent testing to indicate an irradiation weldability relationship. The only influence on the quality of the weld may be the encumbrance of the welder with additional clothing and safety procedures.—U. E.

The Plastic Ductility of Austenitic Piping Containing Welded Joints at 1200° F. R. W. Emerson and R. W. Jackson. (*Welding J.*, 1957, **36**, Feb., 89s–104s). An investigation is described on high temperature testing of steam piping. The effect of heat treatment on grain size and room temperature mechanical properties was studied. It was found that with increase in solution treating temperature 347 and 316 piping showed a decrease in room-temperature tensile strength, yield strength and Brinell hardness.—U. E.

Ductility Related to Service Performance of Heavy-wall Austenitic Pipe Welds. H. M. Soldan and C. R. Mayne. (*Welding J.*, 1957, **36**, March, 141s–150s). The authors correlate results obtained from hot ductility tests developed by Rensselaer Polytechnic Institute with the fabrication and service performance of austenitic steel piping in high temperature central station service. A discussion is included.—U. E.

Properties and Weldability of High Strength Pressure-Vessel Steels in Heavy Sections. J. H. Gross and R. D. Stout. (*Welding J.*, 1957, **36**, March, 157s–167s). The effects of plate thickness and of position in the plate on the mechanical properties and weldability of high strength pressure vessel steels was studied.—U. E.

New Methods of Testing Weldability. M. K. Shorshorov. (*Brit. Welding J.*, 1957, **4**, May, 239–243). Three tests used in the U.S.S.R. are described: a bead test to investigate changes in the heat-affected zone, a hot-cracking test similar to the Murex test, and a method for simulating the weld thermal cycle. Results of tests on various materials are shown.

Effective Control of Welding Fumes. S. E. Nelson. (*J. Inst. Heating Ventilating Eng.*, 1957, **25**, April, 18–25). Local exhaust equipment is reviewed and a report given of trials to determine required air volumes and velocities and the air-flow resistance of Admiralty standard flexible hose as a guide to fan volume and pressure required in dockyard work. Location and size of hoods are recommended.

A Typical Experience of Welded Material in Service. K. de Munter. (*Lastechniek*, 1957, **23**, May, 82–87). [In English]. Cracking of deck plates in a ship of the Royal Netherlands Navy is described. Analysis, mechanical tests, microstructure and hardness of plate and welds are given. Causes of the original failure and of a second crack that appeared during repair are discussed.

Induction Brazing. A. T. Templin and H. S. Peterson. (*Machine Design*, 1957, **29**, Mar. 21, 150–153). Parts may be redesigned for induction brazing where the numbers required justify the outlay on equipment.

Alloys for Brazing Thin Sections of Stainless Steel. A. S. McDonald. (*Welding J.*, 1957, **36**, March, 131s–140s). The following brazing alloys were considered: 72 Ag/28 Cu, 72 Ag/28 Cu + 0·5 Ni, 85 Ag/15 Mn, 85 Ag/15 Mn + 0·5 Ni, and 68 Mn/32 Ni. Data on wetting tests, base metal solution, penetration characteristics, and oxidation resistance of the alloys are presented.—U. E.

Fundamental Concepts of Oxygen Cutting. R. L. Stoecker and W. B. Moen. (*Welding J.*, 1957, **36**, March, 151s–156s). The physical chemistry of oxygen–iron reactions, gas dynamics of the oxygen stream and various heat transfer mechanisms are studied.—U. E.

How to Slice Thick Steel with Oxygen-Cutting. (*Linde Tips*, 1957, **36**, Spring, 42–43).

Mechanized Oxygen Cutting Contributes to Accelerated Production of Turbine Generators. J. F. Buerkel. (*Welding J.*, 1957, **36**, March, 266–267). Oxygen cutting equipment is illustrated. A number of applications are given.—U. E.

MACHINING AND MACHINABILITY

Study of High Speed Machining (VI). Cutting Speed Effect Based upon Theory of Tool-Chip Contact Area. H. Takeyama and E. Usui. (*J. Mech. Lab.*, 1957, **11**, Mar., 43–50). Cast iron and steel which tend to produce a built-up edge deviate from the theory, especially at lower speeds.

New Leaded Steels Reduce Machining of Large Gears. C. R. Funk. (*Mat. Methods*, 1956, **44**, Dec., 94–95). Large ingots can now be made and properties are tabulated.

Rugged Carbide Tools Speed Die Block Machining. F. W. Lucht and T. Kreuzer. (*Iron Age*, 1956, **178**, Dec. 20, 78–79). The authors give recommendations on tooling, speeds and feeds in die-block machining with bed-type milling machines equipped with carbide tools. Actual examples of typical operations are given.—G. F.

Turning High-Tensile Steels. Introduction of Skiving-Tool for Bar-Turning Operations on Heat-Treated Steels. (*Aircraft Prod.*, 1957, **19**, May, 204–206).

A Method of Assessing the Progress and Behaviour of Wear Patterns on Tungsten Carbide Tools and Some Possibilities for Interpretation. E. Y. C. Sun and W. Heginbotham. (*Microtecnic*, 1957, **11**, (2), 71–75). Indirect measurements of the " temperature centre " and wear centre were made.

Trends in Tooling. How Ready Are Ceramics ? (*Steel*, 1957, **140**, Apr. 15, 126–128). A report of a meeting of the American Society of Tool Engineers giving a review of the present state of development.

Machinability Testing: Science or Fiction ? P. M. Unterweiser. (*Iron Age*, 1957, **179**, Feb. 28, 75–78). The author discusses the science of machinability, aimed at extending tool life and making shop machining far more profitable. He justifies machinability testing and describes the use of radioactive tracers for measuring tool wear.—G. F.

The Mechanism of Metal Cutting. R. Jouty. (*Pub. Sci. Techn. l'Air*, 1957, No. 326, pp. 98). A general review is given of previous work of Piispanen's and Merchant's theories and of experimental methods and results. Measurements on steel are reported and assessed and thermal considerations are reviewed, and the effects of tests with carbide tools. Finally vibrations are considered. (43 references).

The Friction Process in Metal Cutting. I. Finnie and M. C. Shaw. (*Trans. Amer. Soc. Mech. Eng.*, 1956, **78**, Nov., 1649–1657). A coefficient of friction is inadequate to characterize the friction process in cutting, being mainly an indication of the normal stress on the tool face and thus strongly dependent on the shear process in cutting.—D. H.

Some Studies of Angle Relationships in Metal Cutting. J. H. Creveling, T. F. Jordan, and E. G. Thomsen. (*Trans. Amer. Soc. Mech. Eng.*, 1957, **79**, Jan., 127–138). An empirical equation is given, holding over the range investigated, connecting shear angle, rake angle, and friction angle. Current theories were not in agreement with the values obtained.

Contributions to the Energetic Study of Chip Formation in Orthogonal Cutting. F. Eugène. (*Microtecnic*, 1957, **11**, (2), 67–70). A diagram is given representing the various phenomena of chip formation and plasticity.

Transient Interface Temperatures in Plain Peripheral Milling. D. E. McFeron and B. T. Chao. (*Trans. Amer. Soc. Mech. Eng. preprint*, 56–A-89, pp. 9). Equations are presented and their solution enables study of the effects of material and process variables to be made from fundamental data. The intermittent nature of the process increases heat flow from interface to tool as compared with single point turning and increase in workpiece temperature affects interface temperature more than would increase of tool temperature.

A Two Component Lathe Dynamometer. B. L. Ten Horn and R. A. Schürmann. (*Microtecnic*, 1957, **11**, (2), 59–66).

Studies on the Stressed Layer. II. On the Formation of the Stressed Layer due to Machining. K. Ogawa and E. Tsuji. (*Nippon Kinzoku Gakkai-Si*, 1954, **18**, Oct., 499–503). [In Japanese]. In turning operations, the depths of stressed layers were reduced by increasing cutting velocity or carbon content with plain carbon steels, but increased by increasing cutting velocity or nickel content for Ni–Cr steels. Surface quality (measured by roughness) was improved with increased velocities. In grinding, the depths of the stressed layers were less than those for turned surfaces, and hardly varied with carbon content. (12 references).—K. E. J.

Experiments on Grinding. P. Landberg. (*Microtecnic*, 1957, **11**, (1), 18–26). Study of waviness of wheel circumference and work, roughness of work, wheel wear and grinding forces and their possible relation to vibrations and life of the wheel is described.

Dress Your Grinding Wheels While They Work. (*Iron Age*, 1957, **179**, May 2, 96–98). The PFC (Perpetual Form Control) wheel dressing system is outlined.

How Much Do Grinding Fluids Affect Wheel Performance ? J. A. Mueller. (*Iron Age*, 1957, **179**, Feb. 28, 79–81; Mar. 7, 134–135). The author discusses and compares the effects of gases, water-soluble oils, and grinding oils on grinding wheel performance. He also considers the effects of different methods of application of the grinding fluid, and outlines the factors leading to maximum grinding efficiency at the lowest cost.—G. F.

CLEANING AND PICKLING

Recent Developments in Degreasing Operations. (*Corrosion Prevention and Control*, 1957, **4**, May, 45–48). A review with 26 references.

Chelating Agents in Metal Cleaning and Derusting. J. K. Aiken and C. Garnett. (*Electroplating*, 1957, **10**, Feb., 31–35). The characteristics of EDTA in cleaning and derusting operations are discussed. A commercial process which employs EDTA and a hydroxylic chelating agent under cathodic conditions is described in detail.—A. D. H.

Pre-Treatment Tests. (*Corrosion Prevention and Control*, 1957, **4**, May, 62, 66). An account of an investigation by Lewis Berger (Great Britain) Ltd. is given, on the use of paints of known characteristics on surfaces treated by the Jenolite RRN/B process.

Barrel Finishing—How and When to Use It. L. F. Spencer. (*Metal Finishing*, 1957, **55**, May, 48–54). An illustrated review of methods and uses, with notes on cost reduction by the process, is given.

Shotblasting Developments in Metal Surface Preparation. J. Carle. (*Corrosion Prevention and Control*, 1957, **4**, May, 49–55). A review of processes and uses.

Walterisation Derusting and Descaling Products. (*Corrosion Prevention and Control*, 1957, **4**, May, 56). Phosphoric acid processing is described.

This is Barrel Finishing. (*Precision Met. Mold.*, 1957, **15**, Feb., 52–57). A review with illustrated case histories of large and small parts.

Roto-Finish Precision Barrelling. R. C. Liebman. (*Corrosion Prevention and Control*, 1957, **4**, May, 59–61). A review.

The Mechanism of Electrolytic Polishing. M. Cole. (*University of Cambridge Abstracts of Dissertations*, 1954–1955, 183–184). Mechanism is proposed and practical recommendations are made.

The Use of Flame Cleaning. (*Corrosion Prevention and Control*, 1957, **4**, May, 57–58). A brief review.

PROTECTIVE COATINGS

The Surface Metallurgy of Protective Coatings. C. L. Faust. (*Metal Progress*, 1957, **71**, May, 101–106). Alloying of alternate layers by a diffusion heat treatment and the effect of the condition of the basis metal are discussed, also the effects of barrier layers of slowly diffusing metals. Structures are illustrated and described.

Automation Doubles Plating Capacity. L. E. Weeg. (*Indust. Finishing*, 1957, **9**, Feb., 384–387). The design and operation of an automatic plant at the National Lock Co., Rockford, Ill. for Cu, Ni, and Cr plating of miscellaneous small parts are described.—A. D. H.

Operation Units and Unit Phases in Electroplating. J. M. Alameda. (*Electroplating*, 1956, **9**, Dec., 397–399). Electroplating processes are analysed and broken down into unit operations. It is suggested that the system is useful for costing purposes.—A. D. H.

How to Choose Heat Tolerant Coatings. C. L. Faust. (*Steel* 1957, **140**, Apr. 22, 82–84). Choice of metallic coatings is discussed, the properties of suitable metals and alloys being tabulated.

A Guide to " Peen " Plating. (*Indust. Finishing*, 1957, **9**, Mar., 462). An account of a barrel process developed by the Schori Division of F. W. Berk Ltd.

Stress in Electrodeposits. R. Pinner. (*Electroplating*, 1956, **9**, Dec., 391–396; 1957, **10**, Jan., 7–11). The causes of stress in electrodeposits and the method of measurement are reviewed. Factors affecting the magnitude of stress in nickel and chromium deposits and the influence of stress on the mechanical and chemical properties of the coatings are considered in detail. (55 references).—A. D. H.

New Test Checks Electroplating Porosity. F. Ogburn and M. Hilkert. (*Iron Age*, 1957, **179**, Mar. 7, 123–126). The authors describe the development of a new non-destructive radiographic technique for checking porosity and other discontinuities in plated coatings, and give details of its application and interpretation of the results. Its advantages over other methods of testing are discussed.—G. F.

Filtration of Plating Solutions. (*Products Finishing*, 1956, **20**, May, 28–32). Available apparatus is reviewed.

Throwing Index. A New Graphical Method for Expressing Results of Throwing-Power Measurements. R. V. Jelinek and H. F. David. (*J. Electrochem. Soc.*, 1957, **104**, May, 279–281).

Recover That Plating Waste! E. W. Neben. (*Products Finishing*, 1956, **21**, Nov., 36–40). Recovery of acid by distillation and ion-exchange and other metal recovery processes are briefly indicated.

The Selection of Hard-Facing Materials for Lowest Maintenance Cost. N. D. Berrick. (*Engineer Foundryman*, 1956, **21**, Nov., 56–67). A review of hard facing processes, materials and uses, with discussion. Martensitic steels, hard carbides, and other materials are considered and their wear resistances tabulated. Types of electrodes are given and the performance of faced parts in ball mills, crushers, rolls, shovel teeth, and dredgers reviewed. Other points are brought out in discussion.

Hardfacing Service for Industry. (*Welding Metal Fab.*, 1957, **25**, March, 91–97). The manufacture of hardfacing materials, such as stellite castings and cutting tools by Deloro Stellite Ltd. is discussed. The new hardfacing shop is described.—U. E.

New Chrome Plant Completed. (*Indust. Finishing*, 1957, **9**, Apr., 515). A brief account is given of the Port Glasgow works of Fescol Ltd. for chromium electrodeposition.

Problems of Spray Suppression in Chromium Plating. P. J. Ramsden. (*Electroplating Metal Finishing*, 1957, **10**, May, 152–155). An account of the Zero-Mist process using fluorinated surface-active agents, with a review of other methods.

Nickel Plating Procedures. (*Indust. Finishing*, 1957, **9**, Feb., 388–393, 413). The general plating characteristics of the Watts, sulphamate, bright and Kanigen baths for deposition of nickel are reviewed and recent modifications of practice.—A. D. H.

Bright Nickel Plating. I. R. Bellobono. (*Metal Finishing J.*, 1957, **3**, Mar., 111–117, 127). A discussion of co-ordination compounds and their role in bright plating is given. (27 references).

Structure of Chemically Deposited Nickel. A. W. Goldenstein, W. Rostoker, F. Schossberger, and G. Gutzeit. (*J. Electrochem. Soc.*, 1957, **104**, Feb., 104–110). X-Ray and electron diffraction studies of the deposits from the catalytic reduction process are reported. Metallography and etching studies are also considered. The deposit is amorphous and unrelated to substrate or thickness. Lamellæ were disclosed on etching. The material crystallizes at low temperature exothermically.

Limitations of Plated Nickel in Jet Engine Design. R. W. Moeller and W. A. Snell. (*Electroplating*, 1957, **10**, Mar., 74–77, 91). The residual stress, corrosion resistance, and fatigue life of coatings obtained from five different plating solutions are compared. The application of the data to jet-engine design is discussed.—A. D. H.

Inclusion of Fuchsin in Bright Nickel Deposits. J. L. Dye and O. J. Klingenmaier. (*J. Electrochem. Soc.*, 1957, **104**, May, 275–279). Fuchsin, used as a brightener, was recovered from the deposits. A mechanism for its brightening effect is advanced.

The Kanigen Process for Chemical Nickel Plating. (*Rev. Produits Chim.*, 1957, **60**, Feb. 28, 45–46).

Questions and Answers on Galvanizing. D. J. T. Kennedy. (*Indust. Finishing*, 1957, **9**, 382–383). Criticisms of galvanized finishes by consumers are considered and it is concluded that there should be closer liaison between the manufacturer and the galvaniser.—A. D. H.

Developments in Centrifugal Galvanizing. (*Indust. Finishing*, 1956, **9**, Dec., 294–295). The design and operation of a centrifuge used in the galvanising of small parts are described.

Galvanizing of Screws and Other Small Parts. II. W. Peters. (*Draht, German ed.*, 1957, **8**, Jan., 7–13; Feb., 40–48). Modern equipment for galvanizing small parts is described with reference to numerous illustrations, and this is followed by a discussion of various electroplating solutions and of finishing treatments.—J. G. W.

Zinc Coatings Slow Atmospheric Corrosion. B. O. Ellis. (*Indust. Finishing*, 1956, **9**, Nov., 274–276). The atmospheric corrosion characteristics of galvanized sheet are discussed with special reference to Sendzimir continuous galvanized products.—A. D. H.

The Production of Bonderized Electro-Zinc Coated Steel Sheet. (*Metal Finishing J.*, 1957, **3**, Mar., 103–110). An illustrated description of the plant of Margam Electro Finishes Ltd. is given.

The Attack on Iron of Zinc Melts Containing Cadmium. D. Horstmann. (*Arch. Eisenhüttenwesen*, 1957, **28**, Apr., 195–199). It was shown that the addition of Cd will intensify the attack of Zn melts on iron. The temperature range of this attack, which progresses linearly with time, widens as the cadmium content is increased. The intensity of attack is determined by diffusion in the gamma layer.—L. J. L.

A Modern Hot-Tinning Plant. C. J. Thwaites. (*Indust. Finishing*, 1956, **9**, Dec., 268–269). A mechanized plant at the Plymouth works of Tecalemit for the hot tinning of welded steel fire-extinguisher bodies with 70% Sn/30% Pb alloy is described.—A. D. H.

Electrodeposition of Tin as a Bright Coating. A. M. Harper, A. Mohan, and S. C. Britton. (*Metal Ind.*, 1957, **90**, May 17, 421–423). The use of tar dispersions in acid $SnSO_4$ is described. Discussion of the paper is reported.

Tin Plating from the Pyrophosphate Bath. J. Vaid and T. L. Rama Char. (*J. Electrochem. Soc.*, 1957, **104**, May, 282–287).

Alloy Plating. Which Way is it Headed? F. A. Lowenheim and R. T. Gore. (*Iron Age*, 1957, **179**, Apr. 25, 112–113). A review in general terms of two and three metal plating such as Cu–Zn, Sn–Zn, Sn–Cd, Sn–Ni, Sn–Sb, Sn–Co, Pb–Sn and Pb–Sn–Sb, Cd–Sn–Zn and others.

Some Observations on Aluminizing of Steel. A. N. Kapoor, A. B. Chatterjea, and B. R. Nijhawan. (*Trans. Indian Inst. Met.*, 1955–56, **9**, 167–181). Deformability of hot-dip aluminized steels depends on the characteristics of the alloy layer. The thickness of this layer y at any given temperature is related to the time in minutes t by the expression $y = kt^n$ where k and n are constants, $n = 0{\cdot}3$ at lower temperatures but increases to 0·5, the value of a diffusion-controlled process, with increase in temperature. The presence of 0·25% mischmetal with 0·4% Ti and 2% Si gave preferred coating.

Studies on the Rate of Growth of the Alloying Layer of Aluminised Steel. T. Morinaga and Y. Kato. (*Nippon Kinzoku Gakkai-Si*, 1955, **19**, Oct., 578–581). [In Japanese]. Hot-dipped aluminised steel has a layer of thickness $1{\cdot}5–2{\cdot}5 \times 10^{-2}$ mm, consisting of an outer layer of relatively pure aluminium and a relatively pure alloy layer. Increase of carbon content in the steel markedly restrains the growth of the alloy layer. It is not affected by 0·1% and 0·4% of titanium, but an addition of 1·0% is effective in preventing its growth.—K. E. J.

Electrostatic Coating. E. P. Miller. (*Yearly Proc. Assoc. Iron Steel Eng.*, 1956, 305–308). Methods are outlined with special reference to applications in the iron and steel industry.

Automatic Zinc Spraying of Steel Drums. G. A. Curson. (*Welding Metal Fab.*, 1957, **25**, March, 78–81). The Schori model 50 metal powder spraying pistol is described. Powder supplies, fuel gas, and oxygen supplies are discussed with illustrations.—U. E.

Characteristics of Refractory Oxide Coatings Produced by Flame Spraying. N. N. Ault. (*J. Amer. Ceram. Soc.*, 1957, **40**, Mar., 69–74). Examination of Al_2O_3, stabilized ZrO_2 and zircon coatings is reported.

The Modern Chlorate-Accelerated Phosphating Bath. E. Heinzelman jun. (*Metal Finishing*, 1957, **55**, May, 61–64). A brief review of the use of accelerators and the action of chlorates is given.

Condition Water to Cut Phosphating Costs. (*Iron Age*, 1957, **179**, May 2, 99). Use of the Packard water conditioner is outlined to prevent scale adhesion in tanks and coils.

The Use of Epoxide Resin Based Coatings for Corrosion Prevention in a Chemical Refinery. J. L. Francis. (*Corrosion Prevention and Control*, 1957, **4**, Mar., 74–75).

Epoxy Coatings for Metal Products. R. E. Dunbar. (*Mat. Methods*, 1957, **45**, Apr., 130–134). Compositions, application and properties of films are indicated.

"Epikote" Resin Based Coatings: A General Review. D. H. Nicholson. (*Corrosion Prevention and Control*, 1957, **4**, Mar., 55–58, 60, 62, 64, 67). A review of the uses of these epoxy copolymer resins as anticorrosive coating materials.

Can and Drum Coatings. E. E. V. Sharpe. (*Indust. Finishing*, 1957, **9**, June, 326–328). Factors affecting the choice of organic coatings for interior and exterior corrosion protection of steel sheet for cans and drums are discussed.

An Account of Vitreous-Enamelling Practice in a Danish Works. O. Schroeder. (*Metal Finishing J.*, 1957, **3**, Feb., 75–78, 82). Cast iron and sheet iron enamelling are outlined.

Enamelling Aluminium-Coated Steel. J. E. Sams. (*Machine Design*, 1957, **29**, Jan. 10, 146). A brief review of properties and advantages.

The Suitability of Fusion-Welding Processes for Vitreous Enamelling. B. Trehearne. (*Metal Finishing J.*, 1957, **3**, Feb., 79–82). Defects are discussed and measures for overcoming them suggested. X-Ray studies are correlated and the effect of hammering after welding is considered.

Vitreous Enamelling Brings Colour to the Home. (*Indust. Finishing*, 1957, **9**, Mar , 438–442). An account of gas cooker finishing.

Finishes for Luminaires. W. Weibel. (*Products Finishing*, 1956, **21**, Nov., 24–33). White enamelling of reflectors by Curtis Lighting Inc. is described.

Flexibility of Thin Porcelain Enameled Sheet Steel. A. G. Eubanks, J. R. Crandall and J. C. Richmond. (*Amer. Ceram. Soc. Bull.*, 1957, **36**, Feb., 59–63). Tests are described on cracking of thin enamel coatings in bending and deformation. Sheet backing-adhesive combinations were also tested and a paper-rubber emulsion proved to be the best.

Evaluation and Specification of Paint for Industrial Use. J. Bigos. (*Iron Steel Eng.*, 1957, **34**, April, 107–120). Much information is given on the selection of paints and methods of surface preparation and paint application. Detailed specifications are given as well as a code of practice. (21 references).

POWDER METALLURGY

Atmospheres for Sintering Furnaces. N. K. Koebel. (*Metal Progress*, 1957, **71**, May, 91–98). A review with a short treatment of sintering theory.

Role of Grain Boundaries in Sintering. J. E. Burke. (*J. Amer. Ceram. Soc.*, 1957, **40**, Mar., 80–85). During sintering, grain boundaries act either as sinks or as diffusion paths for lattice vacancies. Grain growth changes the configuration of boundaries relative to pores and so influences shrinkage rate. Impurities increase sintering rate if they increase diffusion and also by impeding grain-boundary movement. Work on alumina and other materials is reported.

What You Should Know about Carburized Iron Powder Parts. W. J. Doelker. (*Mat. Methods*, 1957, **45**, Apr., 122–126). Comparison with wrought steels is made and carburizing methods for iron and iron–copper are outlined. Mechanical premixing with its advantages and disadvantages is described.

High Strength Structural Parts By Powder Metallurgy. (*J. Met.*, 1957, **9**, Mar., 331–339). **Theory.** H. H. Hausner. (331–333). The factors influencing the strength of metals produced by powder metallurgy are discussed. The significance of lattice imperfections and density are considered. **Techniques.** G. Stern. (334–335). Some of the techniques employed for producing the more commonly used high-strength, structural materials by powder metallurgy are described. **Applications.** J. M. Copeland. (336–339). The application of most sintering processes is discussed, with specific details of the applications of coining and resintering techniques.—G. F.

Magnets: There's Untapped Strength in Pure Iron Powder. F. E. Jaumot jun. and A. E. Berkowitz. (*Iron Age*, 1956, **178**, Dec. 20, 88–89). The authors discuss the theory of permanent magnets and show that smaller, lighter magnets with a stronger magnetic field can be produced from pure iron powder. Possible production methods are outlined.—G. F.

Why Pay Extra for Properties You Don't Need ? (*Precision Met. Mold.*, 1957, **15**, Jan., 67–69). Powder metal parts are considered for a shock absorber. Comparison with wrought bar, castings and forgings are briefly made.

The Fatigue Properties of Sintered Compacts. O. J. Dunmore. (*University of Cambridge Abstracts of Dissertations*, 1951–1955, 185–186). Torsional fatigue studies on sintered copper are reported.

FERRITES, CERMETS, AND CARBIDES

Effects of Ceramic Parameters on Microwave Properties of Nickel Ferrite. S. L. Blum, J. E. Zneimer, and H. Zlotnick. (*J. Amer. Ceram. Soc.*, 1957, **40**. May 1, 143–149).

Controlled Crystal Anisotropy and Controlled Temperature Dependence of the Permeability and Elasticity of Various Cobalt-Substituted Ferrites. C. M. van der Burgt. (*Philips Res. Rep.*, 1957, **12**, Apr., 97–122). (48 references).

[On Strontium Ferrites]. H. Watanabe. (*Nippon Kinzoku Gakkai-Si*, 1954, **18**, Nov., 588–591). [In Japanese]. X-Ray powder photographs of samples in the system SrO–Fe_2O_3 show at least three phases. The hexagonal magnetoplumbite structure is strongly magnetic, and accounts exclusively for the observed ferromagnetism. A cubic structure, not ferromagnetic at room temperature, corresponds with the composition 0·7 SrO, 0·3 Fe_2O_3; the lattice constant is 3·86 $\times$ n Å., where n is an integer. A phase of unknown crystallographic symmetry occurs at the composition SrO, Fe_2O_3.

Magnesium–Copper–Manganese–Aluminium Ferrites for Microwave Applications. L. G. Van Uitert. (*J. Appl. Phys.*, 1957, **28**, Mar., 320–322).

Magnetic Induction and Coercive Force on Members of the Series $BaAl_xFe_{12-x}O_{19}$ and Related Oxides. L. G. Van Uitert. (*J. Appl. Phys.*, 1957, **28**, Mar., 317–319).

Dispersion Relations for Tensor Media and their Application to Ferrites. B. S. Gourary. (*J. Appl. Phys.*, 1957, **28**, Mar., 283–288).

Experimental High-Temperature Materials for Gas Turbines. A. R. Edwards. (*Trans. Australian Inst. Met.*, 1955, **7**, **8**, 231–236). A review of sintered oxides, carbides etc., cermets, and alloys of Mo and Cr is given. Comparisons with steels are reported.

Cermets. J. R. Baxter. (*Trans. Australian Inst. Met.*, 1955, **7**, **8**, 237–242). A review.

PROPERTIES AND TESTS

Surface Inspection of Hot Rolled Coil Rod and Bars. W. C. Campbell. (*Yearly Proc. Assoc. Iron Steel Eng.*, 1956, 427–431). An account is given of faults occurring in rods for cold heading and forming into nuts, bolts and similar products, with methods of testing and inspection. Fluorescent magnetic inspection is described.

Suitability of the Envelope Line as a Reference Standard for Measuring Roughness. H. von Weingraber. (*Microtecnic*, 1957, **11**, (1), 6–17). An attempt to find a suitable reference line led to the envelope profile which is analysed and methods for its determination suggested.

How to Test Tool Steels. H.-D. Weckener. (*Mech. World*, 1957, **137**, May, 198–201). Chemical and mechanical tests and their interpretation are outlined and typical values are tabulated and microstructures shown.

Temperature Dependence of Young's Modulus in Plain Carbon Steels. B. N. Das and S. K. Banerjee. (*Trans. Indian Inst. Met.*, 1955–56, **9**, 195–206). Young's Modulus was determined for six plain carbon steels of carbon content 0·23–1·00% at temperatures up to 700° C. A dynamic method similar in principle to Förster's was used. At room temperature the modulus varied within the range 30·4–30·7 $\times$ 10^6 lb/in² for all the steels tested. The temperature coefficient up to 400° C was $-$ 0·01 $\times$ 10^6 lb/in² for the lower carbon contents and $-$ 0·0085 lb/in² for 0·6% C and above. Above 400° C the rate of fall of modulus with temperature was accelerated.—D. H.

The ΔE-effect, Young's Modulus and Their Change Due to Quenching in Iron–Aluminium Alloys. M. Yamamoto and S. Taniguchi. (*Nippon Kinzoku Gakkai-Si*, 1954, **18**, Nov., 584–588). [In Japanese]. Results are given for the variations in the ΔE effect and Young's modulus in ferromagnetic alloys containing up to 17% of aluminium, in the annealed and quenched states, measured by the magnetostrictive vibration method. The ΔE effect shows an increase with the superlattice formation of Fe_3Al. Low values of Young's modulus are found at 13% Al, but this has no direct correlation with the Fe_3Al superlattice. (26 references).—K. E. J.

Improving Hot-Ductility of 310 Stainless. R. A. Perkins and W. O. Binder. (*J. Met.*, 1957, **9**, Feb., 239–245). Under certain conditions of manufacture, austenitic stainless steels exhibit a tendency to hot-crack during fabrication. The authors have studied the effect of deoxidation procedure on the hot-ductility of such steels, and have investigated additions of Si, Mn, V, Al, Ti, Zr, Ce, and Ca. The importance of the deoxidation procedure is demonstrated, and its relationship with hot-ductility, microstructure, and inclusions is discussed. A general behaviour pattern is noted.—G. F.

The Flow and Fracture of Nodular Cast Iron. W. R. Clough and M. E. Shank. (*Trans. Amer. Soc. Mech. Eng. preprint*, 56-A-110, pp. 9). Tests on pearlite nodular iron disclosed constant modulus of elasticity and Poisson's ratio. A density change occurs due to separation of matrix from graphite. Fracture occurs normal to greatest applied tensile stress and a considerable internal crack network opens up before fracture. Cleavage fracture is not obtained in tension but may be shown in presence of notches or at low temperature. (23 references).

Dislocation Locking and Fracture in α-Iron. J. Heslop and N. J. Petch. (*Phil. Mag.*, 1957, **2**, May, 649–658). The effect of Mn in iron is studied and it is concluded that the ductility

it confers is associated with weakened dislocation locking as well as grain refinement. The weakening appears to be due to interaction between N and Mn.

Relationship between the Fracture Ductility Transition and Strain Hardening Characteristics of a Low Carbon Steel. J. M. Krafft, A. M. Sullivan and G. R. Irwin. (*J. Appl. Phys.*, 1957, **28**, Mar., 379–380). The marked temperature dependence of brittle fracture tendency is explained in terms of strain hardening characteristics during rapid plastic deformation.

On the Applicability of Notch Tensile Test Data to Strength Criteria in Engineering Design. J. D. Lubahn. (*Trans. Amer. Soc. Mech. Eng.*, 1957, **79**, Jan., 111–115). The use that can be made of the data is limited. The information required and possible methods of obtaining it is discussed.

Metallurgical Yield-Stress Observation. Stressing Metallograph Used to Study Mechanism of Failure of Grain Structure of SAE 1055 Steel. J. W. Jacobson. (*Mech. Eng.*, 1957, **79**, Jan., 13–15). Elongation is noted before the yield point is reached, this point is called the metallurgical yield point. Failure occurs initially in ferrite; slip planes are caused by protrusions of pearlitic grains and starting at grain boundaries pass into and across ferritic grains.

Neutron Radiation Effects on Tensile and Impact Properties of ASTM–A302B Steel. E. E. Baldwin. (*Mech. Eng.*, 1957, **79**, Mar., 261–265). The effects of $3{\cdot}7 \times 10^{18}$ nvt neutron flux between 500–700° F gave changes of $< 10\%$ in mechanical properties. There is evidence that larger amounts of radiation will result in greater changes. Some annealing occurs at these temperatures.

The Spring Back of Metals. F. J. Gardiner. (*Trans. Amer. Soc. Mech. Eng.*, 1957, **79**, Jan., 1–9). A mathematical treatment of the spring-back correction curve for pure bending is given. Its application to tooling is exemplified.

Influence of Repeated Bending Loads on Biaxial Residual Stresses in Shot-Peened Plates. T. M. Elsesser. (*Trans. Amer. Soc. Mech. Eng. preprint*, 56–A-109, pp. 6). The plates were sectioned and curvature measurements made to evaluate residual stress distribution near the surface. These were found to decrease to half in 10200 load cycles in the SAE 4340 steel used, more rapidly in the early stages.

Movement of Dislocations. J. J. Gilman and W. G. Johnston. (*Metal Progress*, 1957, **71**, Mar., 76–77). Examples are shown of the movement of dislocations during annealing and plastic bending. The illustrations are of lithium fluoride and show by analogy how dislocations probably move in metal crystals.—B. G. B.

A Torsion-Testing Machine for Spot Welds. T. M. Roberts. (*Brit. Welding J.*, 1957, **4**, May, 243–245). Visual examination of fracture faces is used. The method is of limited application as welds in material thinner than 0·48 in. generally fail in the surrounding area.

The Influence of Shank Area on the Tensile Impact Strength of Bolts. J. Love jun. and O. A. Pringle. (*Trans. Amer. Soc. Mech. Eng.*, 1956, **78**, Oct., 1489–1496). The effect of reduction of shank cross-sectional area on the tensile impact strength of $\frac{5}{16}$, $\frac{3}{8}$ and $\frac{7}{16}$ in. steel bolts was investigated experimentally. Low carbon $\frac{3}{8}$ in. bolts with rolled threads absorbed maximum impact energy when the ratio of shank area to thread-root area was equal to 1·25, heat treated medium carbon $\frac{3}{8}$ in. bolts absorbed maximum energy when the ratio was 1·17 for shanks reduced by drilling or 1·12 for shanks reduced by turning. Results for other sizes were similar. For maximum energy absorption the shank area should be approximately equal to the mean or tensile-stress area of the threads with minor corrections to compensate for work hardening due to thread rolling or surface oxidation resulting from heat treatment.—D. H.

The Low-temperature Impact Properties of Cast Steel. W. J. Jackson and G. M. Michie. (*J. Iron Steel Inst.*, 1957, **187**, Oct., 104–120). [This issue.]

Cold Work Improves Age Hardening Stainless. J. T. Richards and E. M. Smith. (*Metal Progress*, 1957, **71**, May, 71–75). Effects of cold rolling and heat treatments on the physical properties of stainless, precipitation-hardening steels.

Tensile and Fatigue Tests on Normalized Pearlitic Nodular Irons. G. N. J. Gilbert and K. B. Palmer. (*Brit. C.I. Res. Assoc. J. Res. Dev.*, 1957, **6**, Feb., 498–504). These tests on as-cast and normalized pearlitic nodular irons between 1·63 and 2·56% Si are compared. Normalizing is shown to increase proof stress, tensile strength and hardness, and elongations in the tensile test are also improved. Normalizing which results in a marked increase in tensile properties does not result in a correspondingly large increase in fatigue properties.—B. G. B.

Fatigue Under Triaxial Stress: Development of a Testing Machine and Preliminary Results. J. L. M. Morrison, B. Crossland, and J. S. C. Parry. (*Proc. Inst. Mech. Eng.*, 1956, **170**, (21), 697–712). The device can apply internal pressure to cylinders up to 3000 atm. Tests are described and possible explanations for the low results found are advanced.

Reports on Fatigue Failures. International Institute of Welding, Commission XIII: Fatigue Testing. (*Brit. Welding J.*, 1957, **4**, May, 231–238). Reports received in response to a questionnaire are published. The axle arm of a washing machine, the front axle of a lorry, a welded press frame, a stainless steel mixer arm and the failure of a pipe at a flange are described.

On the Fatigue Test of Hollow Drill Steel by a Fatigue-Testing Machine of Electromagnetic Resonance Type. M. Uchiyama and F. Seki. (*Tetsu to Hagane*, 1956, **42**, Aug., 652–655). [In Japanese]. Ten steels (compositions given), heat-treated in various ways, were tested. The fatigue limits of hollow rods were in the range 20–30 kg/mm², being more affected by heat treatment than composition of the steel. Steels with a troostite microstructure, of Vickers hardness approx. 400, gave maximum fatigue strengths. The surface conditions of the rods had a marked effect on fatigue strength. (15 references).—K. E. J.

A Fatigue Testing Machine for Reversed Bending and Steady Torque. H. H. Mabie and M. S. Gjesdahl. (*Proc. Soc. Exper. Stress Anal.*, 1956, **14**, (1), 83–88). The machine tests 1-in. diameter shafts.

Automatic Frequency-Control System for a High-frequency Resonant-type Fatigue Testing Machine. C. L. Temes. (*Proc. Soc. Exper. Stress Anal.*, 1956, **14**, (1), 89–98). Amplitude is also regulated. The machine tests cantilever specimens over the range 500–2000 cycles/s and maintains constant stress amplitude during the decrease of resonant frequency resulting.

Measuring Non-uniform Residual Stresses by the Hole Drilling Method. R. A. Kelsey. (*Proc. Soc. Exper. Stress Anal.*, 1956, **14**, (1), 181–194). Stresses varying with depth below the surface can be measured by the technique described, down to about half the hole diameter.

On the Fatigue Strength of Medium Carbon Steel Shafts Built-up by Arc Welding. (*Lastechn.*, 1956, **22**, Nov., 195–200). [In Dutch]. This is a report from the Centrum v. Lastechnick N.V.L., TNO and concerns an investigation on the premature fracture of built-up welded steel shafts. The results indicate that the trouble is mainly attributable to defects in weld deposits or the heat affected zone. Tests conducted on faultlessly built-up welded shafts to determine whether they showed low fatigue strength indicated that provided all precautions are taken to ensure a sound weld deposit, satisfactory fatigue strength values for shafts of the type under discussion are obtainable.—F. R. H.

The Behaviour of Materials under Repeated Stress—Use of a Recrystallization Method to Study the Nature of Damage in Fatigue of Metals. G. M. Sinclair and T. J. Dolan. (*PB.* 110481, 1951, pp. 19; TIDU List 507). Work-hardening was periodically removed by annealing during repeated stressing. The finite fatigue life was not significantly improved so that it is concluded that disruption of bonds is initiated during an early stage of cyclic stressing.

On the Shot for Peening. IV. Residual Stress and Fatigue Limit. K. Kamishohara. (*Tetsu to Hagane*, 1956, **42**, Mar., 186–187). [In Japanese]. Results are given for fatigue tests with a Schenck machine on a steel of given composition (0·56% C). For the same heat-treatment, viz. oil-quenching at 850° C and tempering at 580° C, the improvement of fatigue behaviour by peening with soft and hard shot is shown on a S–N diagram.—K. E. J.

An Automatic Electromechanical Stressing Unit for Creep and Fatigue Testing. A. J. Kennedy and R. F. Slade. (*J. Sci. Instruments*, 1956, **33**, Nov., 409–410). The test proceeds under constant stress or constant load, as required, and creep strain and stress error are recorded. Creep recovery or stress relaxation tests can also be carried out.

Creep Relaxation for Combined Stresses. J. E. Griffith and J. Marin. (*J. Mech. Phys. Solids*, 1956, **4**, Aug., 283–293). Advice for testing thin-walled tubes is described and used to check a theory for predicting relaxation-time relations for creep.

Studies on Mechanical Properties at Elevated Temperature of Timken 16-25-6. III. T. Hasegawa, O. Ochiai, and J. Ino. (*Tetsu to Hagane*, 1956, **42**, July, 573–578). [In Japanese]. Hot–cold worked specimens exhibited stress concentrations along the diagonal lines (square section) or at the centre (round sections). Creep resistance increases with the amount of reduction, to a maximum whose value depends on the working temperature and the treatment before working. Creep characteristics of specimens from different positions in a square bar are compared.—K. E. J.

Bursting Tests of Turbo-Generator Shaft Forgings. K. Sakabe. (*Tetsu to Hagane*, 1956, **42**, Mar., 208–209; 209–211). [In Japanese]. Particulars are given of the variation in mechanical properties along a shaft of Ni–Cr–Mo steel, and of the defects found. Details are given of bursting tests, of a disc which burst at 7860 r.p.m., and of porosity and hair-line cracks found.—K. E. J.

The Evaluation of Hardness. L. Orsini. (*Rivista Mecc.*, 1955, **6**, Oct. 15, 15–16). [In Italian]. A brief description is given of the various methods of determining hardness. Particular reference is made to Brinell, Rockwell, and Vickers tests.—M. D. J. B.

Limitations of the Hardness Test as a Method of Control of the Mechanical Properties of Quenched and Tempered Steels. A. A. Arantes. (*Bol. Assoc. Brasil. Met.*, 1956, **12**, Apr., 135–143). [In Portuguese]. An analysis of 16 carbon and low-alloy steels has been made with reference to the relationship between the hardness, ultimate tensile strength, impact strength, and wear-resistance. The following observations were made: *i*, the relationship between hardness and tensile strength is approximately the same for most of these steels; *ii*, there is no definite relationship between hardness and impact strength in so far as the hardness does not define the toughness; *iii*, there are many heat-treatments which can give similar hardness values though the other mechanical properties are inacceptable; *iv*, hardness tests are not sufficient to define the mechanical properties when control of composition and heat-treatment is not possible, and *v*, as an acceptance test of steels softer than R_c50, a complementary test such as hammer-bending could be used to give data with regard to ductility and toughness.—P. S.

Microhardness Tests and Validity of Meyer's Law. A. Molaroni. (*Met. Ital.*, 1956, **48**, Oct., 443–446). [In Italian]. The author describes a series of tests conducted to determine microhardness. The tests were carried out with small loads (300 g) on materials with very variable hardnesses (80 to 800 Vickers). Results are analysed by statistical methods and a value of 'n' in Meyer's formula $P = Kd^n$ is established. The results of the various tests indicate that the formula is correct to 1%. The value of 'n' varies within 1·93 and 1·98 according to the material. (6 references).—M. D. J. B.

Further Development of the End-Quench Test for Appraisal of the Hardenability of Deep-Hardening Steels. A. Rose and L. Rademacher. (*Stahl u. Eisen*, 1956, **76**, Nov. 15, 1570–1573). The end-quench test so far applicable only to plain or low-alloyed steels could be extended to medium alloyed steels by the use of a "cap" that covers the test pieces for 60 mm. The greatest diameter of the cap is 70 mm and its rather large mass transmits heat to the sample during the end-quench operation, i.e. the quenching is slowed down below the critical rate. This is necessary when testing steel that shows a somewhat sluggish transformation, e.g. the hot-working steels 45 CrMoV 6 7 and 45 CrVMoW 5 8.—T. G.

Observations on the Determination of Grinding Microhardness. H. Tertsch. (*Radex-Rundschau*, 1956, May, 115–118). The principles and essential differences in determining microhardness by grinding and by penetration methods are described; the methods measure different properties and cannot be compared. The Schneiderhöhn light lines of the grinding method denote hardness differences between one grain and another. Although only providing a qualitative measure of hardness, the grinding method has many advantages.

Influence of C on the Properties of 18-4-2 Type High-speed Steel. M. Kitahara. (*Tetsu to Hagane*, 1956, **42**, Mar., 378–380). [In Japanese]. The quenched hardness rises with C content to a max. at approx. 0·8% C (varying slightly with temperature between 1100° and 1300° C), and then tends to become constant. The bending strength and deflection follow opposite trends (shown graphically).—K. E. J.

Stretch Forming under Fluid Pressure. P. B. Mellor. (*J. Mech. Phys. Solids*, 1956, **5**, Nov., 41–56). Hydrostatic bulging of a circular diaphragm is studied. Development of strain and instability is observed and a hardening characteristic derived for each metal examined.

Study of Heat-resisting Steels. XI. E. Asano. (*Tetsu to Hagane*, 1956, **42**, Mar., 201–203). [In Japanese]. Hardness and reduction of area are plotted for a titanium steel, a boron steel and Timken 16–25–6 alloy (analysis given), after hot-working and various periods of tempering.—K. E. J.

The Effect of Tensile Straining on the Ageing of Temper-rolled Steel Sheet. B. B. Hundy and T. D. Boxall. (*Sheet Metal Ind.*, 1956, **33**, Dec., 857–862, 874). Extra-flat deep-drawing sheet is sometimes produced by stretching slightly after temper rolling. The object of the work described was to determine how this treatment would affect the ageing behaviour of steel sheet. It was found that, when the temper-rolling reduction was very light ($\sim 0{\cdot}5\%$), the stretching was generally beneficial in that it tended to delay the return of the yield point. For heavier reductions ($> 1{\cdot}0\%$), stretching still delayed the return of the yield point in the transverse direction but accelerated its return in the rolling direction. The optimum practical procedure would seem to be to use a rolling reduction of $1{\cdot}0\%$ and limit the stretch to as small a strain as possible, consistent with obtaining flat sheet ($< 1{\cdot}0\%$).—A. H. M.

Ageing of Medium-Carbon Aluminium-killed Steel. T. Kaneda. (*Tetsu to Hagane*, 1956, **42**, Mar., 351–353). [In Japanese]. Steels made by various processes were tested. Results are given for the change in yield strength after pre-straining 5% in tension and ageing at 230° C, for Al-killed and Si-killed normalized and spheroidized steels. Curves of impact value against temperature (− 120° to + 100° C) are given for steels killed in the two ways, spheroidized, spheroidized and cold-drawn, normalized, and normalized and cold-drawn.—K. E. J.

The Application of Ultrasonics to the Measurement of Wall Thickness in Grey Castings. R. Zeigler and R. Gerstner. (*Giesserei, Techn.-Wissensch. Beihefte*, 1956, Sept., (16), 829–835). The principle of the method is outlined and the method of measuring the apparent wall thickness and the relative velocity of sound described. The inter-dependence of the degree of saturation, the Brinell hardness, the wall thickness and the graphite content of the cast iron are investigated. The practical measurement of wall thickness is then described, with a discussion on the shortcomings of the method and the accuracy of the measurements.—R. J. W.

Industrial Testing of Thin Sheet by Means of Ultrasonics. H. Beuse and H. Hartwig. (*Z. VdI.*, 1956, **96**, July 11, 1057–1061). A simple and economical testing method for the presence of laminations, and nonmetallic inclusions in deep drawing sheet has been developed, based on oblique ultrasonic and inclined at an angle ranging from about 25° to 36°, depending on sheet thickness (within range investigated 0·036–0·044 in.). For optimum results the two units are aligned in the direction of rolling and traversed at right angles to it. A traversing speed of up to 2 in./s is practicable. A semi-automatic sorting apparatus, which has so far sorted 100,000 sheets, is illustrated.—J. G. W.

Report on Ultrasonics. (*Indust. Finishing*, 1956, **9**, Aug., 20–26). Industrial applications of ultrasonic cleaning in Great Britain, Germany, and U.S.A. are reviewed in three articles by O. Kennedy, S. Spizig, and T. A. Dickinson.

Ultrasonics and Their Application to the Inspection of Welded Joints. A. Ruiz Rubio. (*Gen. Tecn. Solda.*, 1956, **6**, Jan.-Feb., pp. 23). [In Spanish]. A general discussion of the principles of ultrasonic inspection is given and followed by a detailed description of weld inspection by this method; particular attention is given to the beam directions and the influence of the shape and position of the defects upon the echoes obtained. The examination of five test welds is then reported, and in the fifth example the distribution of the defects as deduced by the ultrasonic tests are shown to correlate exactly with those revealed by radiography. The importance of calibration prior to inspection is stressed, and the complementary use of radiography and ultrasonics is indicated.—P. S.

Ultrasonic Detection of Flaws in Forgings. D. P. Valuev, R. N. Il'ina, B. N. Masharskiĭ, and P. D. Khinskiĭ. (*Vestnik Mashinostroeniya*, 1954, **34**, (12), 63–64). A flaw detector, made in the U.S.S.R. (UZD–9), was used to test large forgings. A concentric arrangement of flaws was detected in scanning. A zone of this kind had not been observed previously, and polished sections showed no flaws except for some extremely

fine inclusions on microscopical examination. Sulphur and phosphorus prints disclosed the same annular zone containing an increased quantity of inclusions.

Detection of Internal Defects in Rails by Ultrasonic Methods. The Sonirail. J. Palmé. (*Rev. Mét.*, 1955, **52**, Sept., 711–717). Results given by conventional ultrasonic methods are often governed by the efficiency of the quartz–steel contact and by the absorption factor of the material. Instruments have been developed where the detection of a defect is dependent not only on the signal intensity but also on its frequency.

Some Experimental Results on Defect Detection by a Supersonic Thickness Gauge. K. Kawano. (*Tetsu to Hagane*, 1956, **42**, Mar., 206–208). [In Japanese]. Results of tests, and accuracy figures, are given for the " Sonizon " instrument.

The Recording of Defects in the Ultrasonic Impulse Running Time Process. E. Martin and K. Werner. (*Arch. Eisenhüttenwesen*, 1956, **27**, Sept., 579–594). The non-destructive ultrasonic testing of rails and shafts etc. in railway engineering is described. The methods of recording defects parallel with and across the longitudinal axes of pieces under test simultaneously are discussed in great detail.—L. J. L.

Let Ultrasonics Probe Proper Part Thickness. P. K. Bloch. (*Iron Age*, 1956, **178**, Sept. 13, 100–101). Examples are given of the use of ultrasonic resonance gauges for rapid and accurate thickness determinations on difficult parts.—D. L. C. P.

Echo Phantoms. M. A. Kassem. (*Iron Steel*, 1956, **29**, Nov., 503–509; Dec., 547–549). The author has studied the origin and behaviour of spurious echoes inherent in ultrasonic flaw detection, and furnishes a complete identification of the echoes, taking into account both their number and distribution relative to the main echoes. A rational designation of all the echoes is proposed, and a general echo chart for all solids is established. The use of the echoes for non-destructive determination of elastic constants has been investigated, and high accuracy and experimental convenience are claimed.—G. F.

International Conference on Non-Destructive Methods for the Study and Control of Materials. Y. Verwilst. (*Acier Stahl Steel*, 1956, **21**, June, 257–260). [In French]. The author gives a brief review of the various non-destructive methods available today for the testing of materials. X-Rays, ultrasonics, and magnetic methods are discussed. Information is given on the apparatus commercially available.—M. D. J. B.

Experiences with and Possible Applications of X-Ray Testing Equipment, Isotopes as Tracers and Ultrasonic Echo Apparatus in the Steel Foundry. H. Zeuner. (*Giesserei*, 1956, **43**, Aug. 30, 566–571). The use of X-rays and γ-rays for the radiography of steel castings is reviewed. Various radioactive isotope containers available on the market are described. The cost of radiography using ^{60}cobalt is tabulated. The technique of investigating faults in steel castings by ultrasonics is described and illustrated.—R. J. W.

Standard X-Ray Diffraction Powder Patterns. H. E. Swanson, N. T. Gilfrich, and G. M. Ugrinic. (*Nat. Bur. Standards, Circular* 539, 1955, **5**, Oct. 21, pp. 75). Data for pyrites is given.

X-Ray Diffraction Effects of Atomic Size in Alloys. B. Borie. (*Acta Crystallographica*, 1957, **10**, Feb., 89–96). Mathematical.

The Origin of Small Angle Scattering of X-Rays in Plastically Deformed Metals. A. Seeger. (*Acta Met.*, 1957, **5**, Jan., 24–28). [In German]. A theory is presented that the observed additional scattering is due to dislocations and not to the voids hitherto postulated.

Studies on Ball-bearing Steels. VI. X-ray Determination of Retained Austenite by Integrated Intensities. M. Ueno. (*Tetsu to Hagane*, 1956, **42**, Mar., 257–259). [In Japanese]. The theory of the method is explained and illustrated by references to tube, acid open-hearth, basic electric furnace, and ball-bearing steels.—K. E. J.

Applications and Problems in Stroboradiography. C. Mitchell and R. A. Pulk. (*Nondestructive Test.*, 1956, **14**, Sept.-Oct., 24–27, 31). Application of the stroboscopic principle to the radiographic study of mechanisms undergoing high-speed repetitive motion, by using synchronized bursts of X-radiation from the 5 to 15-Mev betatron, is discussed. The construction of the synchronizing device is described, and some initial results from the Detroit Arsenal are presented.—A. H. M.

Materials Used in Nuclear Reactors, their Characteristics and Behaviour in Particular Conditions of Heat and Radiation. R. Lazzerini. (*Calore*, 1956, **27**, Sept., 423–436; Oct., 475–502). [In Italian]. The author gives a brief description of the operation of a nuclear reactor and discusses the mechanism of the transmutations which are induced by the radiations. The properties of the various materials and their characteristics are described and the changes which take place in their physical and mechanical properties are studied. (48 references).

Inelastic Scattering of Protons from Isotopes of Sc, Mn, Fe, Ni, and Cu. P. M. Wyndham, C. R. Gossett, G. C. Phillips, and J. P. Schiffer. (*Phys. Rev.*, 1956, **103**, Sept. 1, 1321–1326). Cross-sections for ^{54}Fe and ^{56}Fe are given.

Neutron Diffraction Study of Annealing Textures in Drawn Body-Centred-Cubic Metals. R. A. Swalin and A. H. Geisler. (*Trans. Amer. Inst. Min. Met. Eng.*, 1956, **206**; *J. Met.*, 1956, **8**, Oct., Section 2, 1259–1263). Using neutron diffraction techniques, the authors have studied annealing textures of cold-drawn body-centred cubic metals as a function of annealing temperature, and found the [110] deformation texture to be retained on recrystallization and to become increasingly sharper with increasing annealing temperature. With iron, certain (110) plane orientations yielded more integrated intensity than others; a magnetostrictive effect is considered improbable, and a hypothesis concerning the preferred distribution of grains deviating from the ideal [110] orientation is proposed.—G. F.

The Saturation Vapour Pressure of Metals. E. Waldschmidt (*Metall*, 1956, **10**, May, 400–404; Dec., 1126–1133). Curves for most of the metals are given including iron and Ni, Co, Cr, Mn, Mo, etc.

On the Specific Heat of α-Phase Alloys of Iron and Cobalt. H. Masumoto, H. Saito, and M. Shinozaki. (*Nippon Kinzoku Gakkai-Si*, 1953, **17**, July, 312–314). [In Japanese]. Specific heats of 17 alloys in the α-solid solution range were measured. There are three maxima on the curve of specific heat against concentration, beside that corresponding to the transformation of the FeCo superlattice; these occur between 20 and 29, 34·6 and 66, and 66 and 78% of cobalt. These are attributed to a superlattice of Fe_3Co, lattice transformation of the FeCo superlattice, and a superlattice of $FeCo_3$, respectively.—K. E. J.

The Application of the Leitz Dilatometer according to Bollenrath. J. P. Mulder. (*Chem. Week.*, 1956, **52**, Oct. 27, 781). [In Dutch]. This is a brief description of the Leitz dilatometer used for measuring the difference in expansion of two solid bodies. For the comparison materials use is made, amongst others, of small metal rods of known uniform expansion mounted in quartz glass tubes in conjunction with a prism, light source, photographic plate, and a galvanometer. The electrical part consists of a circular oven fed by a transformer for heating to max. temps of ca. 1300° C. In the case of materials that rapidly oxidize, the tests may be conducted either under vacuum or in a reducing gas.—F. R. H.

Increasing Heat-resistance by Internal Oxidation of Alloys. J. L. Meijering. (*Lab. N. V. Philips' Gloeilampfabrieken, Separaat*, 2411, pp. 6). Iron alloys and other metals are examined for oxygen diffusion and the development of particles of oxide as inclusions noted.

Study on the Hot-workability of Steels. IV. Hot-working Properties of Austenitic Stainless Steels. T. Morishima. (*Tetsu to Hagane*, 1956, **42**, Mar., 251–252). [In Japanese]. Results with considerable scatter are presented for relationships between the total inclusions and hot-workability, and between the oxygen content and the percentages of Al_2O_3 and Cr_2O_3, for 18–8 stainless steel.—K. E. J.

Studies on Mechanical Properties of S 816 at Elevated Temperature. I. T. Hasegawa, O. Ochiai, and J. Ino. (*Tetsu to Hagane*, 1956, **42**, June, 498–502). [In Japanese]. Results are given concerning the effects of temperature of solution treatment and ageing on creep rupture characteristics at 732° C and 26·6 kg/mm².—K. E. J.

High-temperature Power-Plant Materials. A. Levy. (*Aircraft Eng.*, 1955, **27**, Sept., 292–298). Metals and alloys are discussed and their properties tabulated for application to aircraft power plants. Engine design and parts are considered.

The Solid State: Diffusion in Metals and Alloys. O. J. Kleppa. (*Ann. Rev. Phys. Chem.*, 1955, **6**, 119–140). (141 references).

Application of Induction Heating to Metallic Diffusion. N. A. Lockington. (*Metal Treatment and Drop Forging*, 1957, **24**, Jan., 29–33). Chromium, chromium–aluminium, and silicon diffusion is examined by metallographic methods after induction heating of mild steel and other metals in contact with the diffusing metal as powder and a halogenating flux.

Preferential Self-diffusion in Grain Boundaries of Centred Cubic Iron. C. Leymonie and P. Lacombe. (*Acta Met.*, 1957,

studied autoradiographically and an expression is advanced **5**, Feb., 115–117). [In French]. Three very pure irons were for the phenomenon in very thin films. The equation of Birchenall and Mehl is not supported.

Self-Diffusion of Iron in Austenite. H. W. Mead and C. E. Birchenall. (*Trans. Amer. Inst. Min. Met. Eng.*, 1956, **206**; *J. Met.*, 1956, **8**, Oct., Section 2, 1336–1339). Self-diffusion measurements of iron in austenite between 1000° and 1300° C have shown a large increase in diffusivity and decrease in activation energy as the carbon content increases from zero to 1·4%. The interaction of iron ion vacancies and dissolved interstitial carbon atoms is discussed qualitatively.—G. F.

Self-Diffusion of Iron in Molten Fe–C Alloys. L. Yang, M. T. Simnad, and G. Derge. (*Trans. Amer. Inst. Min. Met. Eng.*, 1956, **206**; *J. Met.*, 1956, **8**, Nov., 1577–1580). The authors have measured self-diffusion coefficients of iron in molten Fe–C alloys using the capillary method, the samples being autoradiographed and sectioned to ensure that no significant convection occurred during diffusion. The self-diffusion coefficients are higher, and the heat of activation for diffusion lower, in the higher-carbon alloys. Calculation based on the Einstein-Stokes equation indicates that the diffusing species is ionic iron.—G. F.

Solubility of Hydrogen in Iron/Carbon/Silicon Alloys. (*Found. Trade J.*, 1956, **101**, Nov. 15, 571–575). Discussion of paper by V. B. John and T. Evans, *ibid.*, Aug. 23.

Diffusion of Hydrogen through Iron and Binary Iron–Chromium and Iron-Nickel Alloys at High Pressures and Temperatures. A. A. Shcherbakova. (*Zhur. Priklad. Khim.*, 1956, **29**, (6), 879–884). [In Russian]. It was established that the velocity of hydrogen diffusion through binary Fe–Cr alloys, containing from 0·97 to 41% Cr and Fe–Ni alloys containing from 1·29 to 98·84% Ni, at a pressure of 100 atm and temperatures from 200 to 600° C can be described by the following equation:

$$V = Ke^{-\frac{E}{RT}},$$

where: K = constant, E = activation energy, R = gas constant, T° = absolute temperature. The velocity of hydrogen diffusion through binary Fe–Cr alloys at 100 atm and at temperatures between 200 and 600° C considerably decreases with addition of chromium up to 19%. The velocity of hydrogen diffusion through Fe–Ni alloys under the same experimental conditions considerably increases with increasing Ni from 1·29 to 10%, on further increase from 10 to 20% a considerable decrease in the velocity of hydrogen diffusion takes place.—V. G.

A Theory of Surface Tension of Solids.—I. Application to Metals. A. S. Skapski. (*Acta Met.*, 1956, **4**, Nov., 576–582). A general theory for the surface tension of solids based on the arrangement of their next neighbour atoms, heats of fusion, and the surface tension of the metal at the freezing point is proposed and applied to metals. Existing data fall near to values predicted by the theory.—A. D. H.

Influence of Nitrogen on Some Physical Properties of Ferrite. P. Flament. (*Rev. Mét.*, 1955, **52**, Oct., 793–810). The production of industrially pure ferrite is first described. The influence of nitrogen dissolved within the ferrite upon its impact resistance, the influence of carbon and nitrogen on the tensile properties after normalizing and upon age-hardening after tempering have been studied. From tests carried out on specimens low in carbon and high in nitrogen and on specimens very low in nitrogen and higher in carbon it has been shown that carbon is the main age-hardening agent after tempering at 700° C.—B. G. B.

Influence of Silicon and Aluminum on the Properties of Hot-Rolled Steel. R. H. Frazier, F. W. Boulger, and C. H. Lorig. (*Trans. Amer. Inst. Min. Met. Eng.*, 1956, **206**; *J. Met.*, 1956, **8**, Oct., Section 2, 1269–1276). The effects of silicon and aluminium additions to 11 different steels on the notched-bar properties of the hot-rolled steels have been investigated. Small Si additions lower the ductile-brittle transition temperature but larger quantities, above deoxidation requirements, act as an alloying addition and raise the transition temperature. Increasing Al contents up to 0·2% lower the transition temperature at a rate depending on Si and Mn contents. The variations of ferrite grain size, austenite grain-coarsening temperature, tensile properties, and tear-test properties are also discussed.—G. F.

Contribution to the Study of the Influence of Small Alloy Element Additions in a Cr–Mn–Si Steel. F. Maratray and G. Delbart. (*Rev. Mét.*, 1956, **53**, Nov., 849–883). The results of a comprehensive investigation to improve the hardenability and mechanical properties (in particular impact strength) of steel containing 1% Cr, 1% Mn, and 1·2% Si by small individual or combined additions of Al, Ti, Mo, B, and V are given and discussed. The effect on hardenability was studied on Jominy test pieces. The mechanical characteristics were measured on small test pieces after classical oil quenching, tempering, and isothermal quenching.—B. G. B.

The Effect of Zn on Pig Iron. I. Aoki. (*Tetsu to Hagane*, 1956, **42**, Mar., 292–294). [In Japanese]. The effects on the cooling of iron, the structure and other properties of additions of copper in the range 0–0·5% and Cu–Zn in the range 0·6–2·4% are described.—K. E. J.

Influence of Chemical Composition of Cast Steel on Hot-tearing Tendency. V. S. Oki. (*Tetsu to Hagane*, 1956, **42**, Mar., 247–249). [In Japanese]. The influences of Sn, As, Sb, Bi, Pb, O_2, H_2, and N_2 are discussed.—K. E. J.

Effect of Copper on the Sulphurisation-resistant Property of Cast Iron at High Temperature. H. Nakai. (*Tetsu to Hagane*, 1956, **42**, Mar., 312–313). [In Japanese]. Copper in amounts between 0 and 5·5% was added to specimens containing 3·5–3·9% C. H_2S was passed over these at 900° C. The curve for change in weight fell sharply with copper content to a minimum at 1·0%, then rose again to 5·5%, but did not return to the value obtained for no addition.—K. E. J.

The Measurement of Thermal E.m.f.s in Cast Iron and their Dependence on Silicon Content. F. Stadtler. (*Giesserei, Techn.-Wissensch. Beihefte*, 1956, Sept., (16), 853–855). The experimental arrangement used for the measurement of thermal e.m.f.s in cast iron is described. Relationships between the thermal e.m.f. and the temperature difference with constant silicon content and between the thermal e.m.f. and the silicon content with a constant temperature difference were established. The thermal e.m.f. of white cast specimens was generally lower than that of the grey, from which it was deduced that the e.m.f. is dependent upon the degree of graphitization. A rapid works method for determining silicon content is described.—R. J. W.

Studies on Acid-resisting High-silicon Iron. III. Influence of Added Elements on Mechanical and Acid-resisting Properties and Shrinkage. O. Tojima. (*Tetsu to Hagane*, 1956, **42**, Mar., 294–295). [In Japanese]. The effects of As, Al, Ti, Co, Sn, and Cu are considered. Several of these cause an increase in transverse strength up to max. values at 0·1–0·4%, after which the strengths fall away. Additions of up to 0·05% of several of these also cause an increase in corrosion resistance, followed by a substantially constant effect between 0·1 and 1·0%.—K. E. J.

Influence of Si, Ni, C and Cr on the Properties of 20% Cr Valve Steel. K. Kusaka. (*Tetsu to Hagane*, 1956, **42**, Mar., 376–378). [In Japanese]. The temperatures of commencement and end of the Ac transformation are raised by increase of Si from 0 to 3% and of Cr from 18 to 22%, lowered by increase of Ni from 0 to 4%, and little affected by the C content between 0·5 and 1·0%. The effects of C content between 0·5 and 1·1% on tensile properties (at room temp., 600°, 700°, and 800° C) of the hardened and tempered steel are plotted.—K. E. J.

On the Tempering Hardness of 12% Chromium Heat-resisting Steels. Effect of Single Elements. T. Fujita. (*Tetsu to Hagane*, 1956, **42**, Mar., 383–385). [In Japanese]. The effects of Mo, Cb, W, V, and Ti on tempering hardnesses and tempering times are shown graphically and discussed.—K. E. J.

New Methods in Thermodynamics and in the Calorimetry of Alloys, Their Application to Iron and Steel. W. Oelsen and E. Schürmann. (*Giesserei*, 1957, **44**, Feb. 28, 113–120). The significance of heat theory for the metallurgist and the foundryman is first discussed. The present state of calorimetry is described and conclusions are drawn from the heat content curves of Pb–Cd alloys. Calorimetric procedures adopted at the Institute for Ironworkers at Clausthal are described. The latest development of the Bunsen ice calorimeter is described, and the heat content curves of some iron–carbon alloys given. Measurements of the change of volume and the magnetic properties of the calorimeter are also described.—R. J. W.

Mechanical Properties at Elevated Temperatures of Ductile Cast Iron. F. B. Foley. (*Trans. Amer. Soc. Mech. Eng.*, 1956, **78**, Oct., 1435–1438). The elevated temperature properties of ferritic ductile cast iron for 100° F intervals from 700–

1200° F are listed. The values other than those for short time tensile tests have been computed using the Larson-Miller equation.—D. H.

Relaxation Properties of Steels and Super-Strength Alloys at Elevated Temperatures. J. W. Freeman and H. R. Voorhees. (*Amer. Soc. Test. Mat. Special Publ., No.* 187, 1956, Aug., pp. 97).

New Ultra High Strength Steel. S. J. Rosenberg and C. R. Irish. (*Mat. Methods*, 1957, **45**, May, 145–146). A high-Si Ti-modified 4340 developed by the NBS is described.

Cold Worked 301 Stainless—Still Strong at 800° F. R. A. Lula. (*Mat. Methods*, 1956, **44**, Sept., 100–102).

Thermenol—The Navy's New Alloy. (*Mod. Castings*, 1955, **28**, Dec., 62–63). Properties are given and structures shown of a vacuum-melted Fe–Al–Mo alloy.

Improved Nickel Alloy Sheet Can Be Used up to 1600° F. (*Mat. Methods*, 1957, **45**, Apr., 173). Incoloy T, with 19–22% Cr, 30–34% Ni–Co and 0·75–1·50% Ti is described.

Jet Engine Alloy Withstands 1200° F, 75,000 Psi for 300 Hr. (*Mat. Methods*, 1957, **45**, May, 182). An Fe–Ni–Cr alloy with small amounts of Mo, Ti and B, known as W545, is briefly described and its properties are tabulated.

METALLOGRAPHY

Microstructure: Guide to Better Alloys. W. R. Hibbard jun. (*Iron Age*, 1956, **178**, Dec. 20, 75–77). The author considers that hitherto microstructure has been employed largely as a means for controlling manufacturing processes, many alloys being products of expediency. The limitations of this approach are illustrated by reference to super-alloys and titanium. In the new approach, new and improved materials are being designed on the basis of microstructures that provide optimum properties.—G. F.

Metallography of Low-Carbon Low-Alloy Steels. P. P. G. L. Siriwardene. (*University of Cambridge, Abstracts of Dissertations*, 1954–1955, 194–195). A study was made of the effect of boron in normalized low-carbon steels containing Mo. The carbides found were identified.

On the Study of the Microstructure of Fracture of Metals by Electron Microscopy. I. On the Study of the Replica Method. H. Wakashima. (*Nippon Kinzoku Gakkai-Si*, 1954, **18**, Oct., 528–531). [In Japanese]. An improved methyl methacrylate–aluminium replica is obtained by using partly polymerized methyl methacrylate, polymerizing this around the specimen, dissolving the metal in dilute acid, and applying aluminium by evaporation while the replica is rotated. Replicas of fractured surfaces suitable for the electron microscope are obtained. **II. On Fractured Surfaces of Steel.** H. Wakashima, S. Uemura, and M. Takahashi. (*Nippon Kinzoku Gakkai-Si*, 1954, **18**, Oct., 532–535). [In Japanese]. Fractured surfaces of ductile material, e.g. pure iron and low-carbon steel, consist of small domains of diameter 1–10 microns; the boundary may correspond with the microcrack first induced. Mild steel after fatigue testing contains many cracks originating from grain boundaries. Brittle materials, e.g. high-carbon and quenched Ni–Cr steel, have very flat fractured surfaces, and the domains are larger than in ductile materials.—K. E. J.

Nondestructive Metallographic Examination of Steel Products. I. Mester and E. Fuchs. (*Kohászati Lapok*, 1954, **9**, Oct., 217–227). Description of a nondestructive metallographic method for examination in situ of large components. Various equipments are described for electrolytic polishing and etching of any random surfaces, not necessarily horizontal. A hand microscope built on a special frame is used for metallographic examination and good photomicrographs can be obtained with a 35-mm camera mounted on the microscope. All these instruments are independent of a laboratory and may be used in workshop and store-rooms, or even in the open air without electric power supply.—P. K.

Researches on Carbides in Alloy Steels. K. Kuo. (*Jernkontorets Ann.*, 1957, **141**, (4), 206–230). A review of work much of which has already appeared. The transition metal carbides are surveyed and tempering is discussed. Partition between cementite and ferrite and precipitation hardening are reviewed and findings from hardness measurements, electron microscopy and chemical and X-ray analysis are considered. Carbides in W and Cr–W steels are examined. (39 references).

An Investigation of Striated Inclusions in Mild Steel Plates. Chuang Yu-Chih and Wu Cheung-hang. (*Acta Metallurgica Sinica*, 1956, **1**, (2) 155–164). The inclusions are predominantly of mullite and cristobalite from the attacked layer of fireclay refractories, which is attributed to MnO or MnO, FeO in the liquid steel.

Thermodynamic Investigation of Nonmetallic Inclusions in Steel, I. II. H. Sawamura and T. Mori. (*Mem. Fac. Eng. Kyoto Univ.*, 1956, **18**, Oct., 378–401; 402–413). The effects of Al, Si, and N on austenite grain size is studied and free energy changes in nitride formation evaluated. Equilibria in Al, Si, and Fe nitride precipitation are calculated from the molten state to room temperature. (40 references). Similar studies are then reported on the carbides and nitrides of Ti, Zn, and V, and the formation of inclusions from them is considered.

Dislocation Etch Pits in Silicon Iron. J. C. Suits and J. R. Low jun. (*Acta Met.*, 1957, **5**, May, 285–289). Segregation of C to dislocation sites is shown to be necessary for etch pit production. In regions of heavy deformation pitting may not be observed if C is low but may be formed after low-temperature carburization.

Information from Normal Grain Growth. C. G. Dunn and P. K. Koh. (*Trans. Amer. Inst. Min. Met. Eng.*, 1957, **209**; *J. Met.*, 1957, **9**, Feb., 290–291). The authors have further investigated the rolling and recrystallisation textures obtained from single crystals of Si–Fe in the $(111)[1\bar{1}0]$ orientation. The results are related to their previous work.—G. F.

Effects of the Treatment of Molten Cast Alloys. K. Löhberg. (*Giesserei*, 1957, **44**, Feb. 14, 89–96). The various crystal forms that are produced during the solidification process are discussed, e.g. primary phases in dendritic, polyhedral or globular form. Crystal formation in Al–Si alloys and Pb–Sn alloys are dealt with in detail. The various effects described for these alloys are discussed and conclusions drawn. The crystallization of cast iron with the graphite in lamella or spheroidal form is described, together with the effect of making additions to the melt or varying the carbon content.

Interfaces Between Metallic Crystal Grains. G. P. Chatterjee. (*Trans. Ind. Inst. Met.*, 1955–56, **9**, 275–284). The author attempts under certain simplified assumptions to develop from fundamentals a few simple relations between temperature, surface tension and composition of homogeneous binary alloys leading to a relationship which can be evaluated. If this gives a positive value there is preferential segregation of solute atoms to grain boundary. If the value is negative there is a tendency for solute atoms to segregate with the grains prior to precipitation. Other possibilities and suggestions have been indicated.—D. H.

The Mechanism of Formation of Widmanstätten Structure of α-Iron in Hypoeutectoid Carbon Steels. Ko Tsun and Zhao Gia-Zheng. (*Acta Metallurgica Sinica*, 1956, **1**, 201–208). Steels with 0·27, 0·4, 0·52, and 0·6% C were examined by heating at 860–1240° C and cooling at different rates, or by treating isothermally between 650–750° *in vacuo*. Widmanstätten structure was always accompanied by surface relief of the type associated with bainite. Factors in the process are discussed and it is shown that austenite may transform to bainite as high as 750° C.

Orientation Superstructures in Iron–Nickel Alloys. E. T. Ferguson. (*Compt. Rend.*, 1957, **244**, May 6, 2363–2366). The uniaxial anisotropy induced by reheating in a magnetic field is determined as a function of composition, temperature, and heating time.

Study on the Banded Structure of Steels. Precipitation of Ferrite. K. Furusawa and A. Kojima. (*Nippon Kinzoku Gakkai-Si*, 1954, **18**, Nov., 599–602). [In Japanese]. During continuous cooling from the quenching temperature, ferrite nuclei appeared in the direction of rolling just below the Ar_3 point. Ferrite nucleation was not influenced by the existence of MnS, but its growth seemed to be. Studies of Ni–Cr steels confirmed that the cause of the banded structure was the segregation of non-diffusible elements, e.g. Ni, Cr, Mn.—K. E. J.

On the Continuous Cooling Transformation Curve of High-speed Steel. II. S. Owaku and H. Akasu. (*Nippon Kinzoku Gakkai-Si*, 1954, **18**, Dec., 640–642). [In Japanese]. Investigations were made on steel to J.I.S.4, viz. 18–4–1 + 10 high-speed steel containing 11% Co. Specimens were cooled for varying times and the structures "frozen" by water-cooling. The curve was then determined from the microstructures and hardnesses. Supercooled austenite is most unstable at about 780° C, and the critical cooling velocity is about 26° per min. The curve is compared with that for 18–4–1 steel.—K. E. J.

Studies on Graphite in Cast Iron by Electron Diffraction. II. Crystal Growth of Flake Graphite. G. Shimaoka. (*Nippon*

Kinzoku Gakkai-Si, 1955, **19**, Mar., 229–232). [In Japanese]. The crystal texture of thin, single graphite flakes extracted from molten pig iron was studied by electron diffraction and optical microscopy. Each flake consists of two arrangements of single crystals having definite orientations on each side of the flake surface. The mode of twinning is explicable with reference to β–SiO_2 found as an inclusion; probably nucleation of flake graphite occurs at vacant sites in the β–SiO_2 crystal.

Calorimetric Investigation of the Kinetics of Isothermal Austenite Decay of a Steel with 12% Mn. G. Collette. (*Arch. Eisenhüttenwesen*, 1957, **28**, Apr., 229–235). The austenitic transformation of a steel in the temperature range 200 to 500° C has been studied by the micro-calorimeter method. The energy of activation of carbide segregation within the austenite grains has been determined.—L. J. L.

Thermal Stabilization of Austenite in a 10% Ni, 1% C Steel. B. Edmondson. (*Acta Met.*, 1957, **5**, Apr., 208–215). A study is reported and explained in terms of the diffusion of interstitial solute atoms to preferred sites.

On the Effect of Silicon on the Tempering of Martensite. I. II. M. Ibaragi and T. Okumura. (*Nippon Kinzoku Gakkai-Si*, 1955, **19**, Mar., 223–226; 226–229). [In Japanese]. I. The effect was examined by hardness and differential dilatometric measurements. Silicon contents of steel did not affect the starting temperatures of the first and second stages of tempering, but raised that of the third stage. With steels containing silicon, a retardation of softening was found between 200° and 300° C. II. Magnetic analyses showed that silicon additions lessened the decomposition of retained austenite at low temperatures. The temperature at which the second stage of tempering proceeded at maximum velocity was higher in high- than in low-silicon steels. The precipitation of carbides at each tempering stage was equivalent for high- and low-silicon steels.—K. E. J.

Non-Martensitic Structure of an Fe–Mn–C Alloy After Quenching at 1150° C and Subsequent Deep Cooling. A. Masin, D. Tlusta, and M. Mrazak. (*Acta Techn.*, 1957, **16**, (1–2), 205–209). A new structural element is developed in a 5% Mn 1% C steel.

Application of the Principle of Least Squares to Families of Straight Lines. S. Ergun. (*Indust. Eng. Chem.*, 1956, **48**, Nov., 2063–2068). An example given is the conversion of hexagonal close-packed iron carbide to Hägg carbide.

Observation of Bainite Transformation by Means of the Hot Stage Microscope. K. Tsuya. (*Nippon Kinzoku Gakkai-Si*, 1955, **19**, Oct., 612–616). [In Japanese]. During transformation, surface relief effects were observed on polished specimens, indicating that bainite is coherent with the austenite matrix, and so its mechanism of formation differs from that of pearlite. The surface relief grows slowly, and hence the transformation differs from the martensite transformation. The growth-rate, tilt and shape of the surface relief due to the transformation change continuously as the temperature changes; they are described qualitatively for both directions of the upper bainite $\rightleftharpoons$ lower bainite transformation.—K. E. J.

Sigma Formation in Commercial Ni–Cr–Fe Alloys. F. B. Foley and V. N. Krivobok. (*Metal Progress*, 1957, **71**, May, 81–86). Alloys containing 0·05% C, 1·9% Mn, and 0·7% Si were used and the effects of the silicon are discussed. Bars were hot rolled and then cold rolled with an intermediate anneal and with various heat treatments. Embrittlement is discussed.

Phase-Diagram Study of Alloys in the Iron–Chromium–Molybdenum–Nickel System. C. J. Bechtoldt and H. C. Vacher. (*J. Res. Nat. Bur. Stand.*, 1957, **58**, Jan., 7–19). Alloys in this system were examined after quenching from 2200, 2000, 1800, 1650, and 1500° F. Compositional limits of stability of seven phases are summarized in diagrams.—B. G. B.

On the Solidification Process of Fe–C–Ni, Fe–C–Ti and Fe–C–Mo Alloys. I. Igarashi and K. Ikawa. (*Nippon Kinzoku Gakkai-Si*, 1954, **18**, Oct., 504–509). [In Japanese]. The effects of Ni, Ti, and Mo on hypo-eutectoid Fe–C alloys were studied. Alloys containing some nickel have the eutectic graphite structure, sometimes accompanied by ledeburite, when cooled rapidly. Those containing 0·3–1·4% Ti showed the eutectic graphite structure when furnace-cooled; higher proportions gave a mottled structure. Mo produced mottled structures with anomalous cooling curves.—K. E. J.

On the Effect of Alloying Elements on the Solubility of Carbon in Molten Iron. K. Sanbongi, M. Ohtani, and K. Toita. (*Sci. Rep. Res. Inst. Tôhoku Univ.*, 1957, **9**, Apr., 147–158). Solubilities in Fe–C–Si, Fe–C–Cr, and Fe–C–Mn are determined at 1540° C. The effects are generalized and discussed in terms of the Periodic Table where the effects of elements of the second short and first long periods are considered and a theoretical equation is deduced and applied to the systems Fe–C–Cr–Si and Fe–C–Mn–Si at 1400° C.

A Thermodynamic Study of the Fe–C System. II. The Stable Iron–Graphite Equilibrium. Chou Yuan-hsi. (*Acta Metallurgica Sinica*, 1956, **1**, (2), 209–220). Studies from existing data are reported, the equilibria are examined and liquidus and solidus curves are calculated.

A Scale of Martensite Microstructures. A. P. Gulyaev A. A. Kolesanova, and E. I. Malinkina. (*Zavodskaya Laboratoriya*, 1956, **22**, (3), 314–315). [In Russian]. A series of martensite microstructures at magnifications of 500 are presented facilitating decisions on whether or not steel has been overheated during hardening. The appropriate structures for various steels are indicated.—S. K.

The Crystallography of Martensite Transformations.—IV. Body-Centred Cubic to Orthorhombic Transformations. J. K. Mackenzie and J. S. Bowles. (*Acta Met.*, 1957, **5**, March, 137–149). The general theory of martensitic transformations (*ibid.* 1954, **2**,) is applied to the B.C.C. to orthorhombic change. Two classes are proposed depending on whether the $\{111\}_0$ or $\{110\}_0$ planes in the final structure is twinned. The predictions of habit planes, orientation relationships and directions of homogeneous strain are satisfactory for Ti and other metals and afford further confirmation of the hypothesis that inhomogeneous shear is a part of a twinning shear in the final structure.—A. D. H.

A Micrographic Study of Mo–Cr and W–Cr Rich Alloys of Mo–Cr–Fe and W–Cr–Ni Systems. H. Bückle. (*Rev. Mét.*, 1957, **54**, Jan., 9–15). Part of the Mo–Cr–Fe system has been investigated by metallographic examination and microhardness testing. The results obtained are discussed in the light of published data on the Mo–Cr part of the ternary system. The microhardness of the individual phases in the W–Cr–Ni system has been measured and the constitution of the tungsten corner of the ternary system derived.—B. G. B.

CORROSION

Research into Corrosion and its Prevention. Work in Progress on Show at S.C.I. Corrosion Group Exhibition. (*Metal Finishing J.*, 1957, **3**, Feb., 64–66). The Drewitt thickness tester, the use of radioactive tracers in study of corrosion inhibitors, measurement of cathodic polarization, and examples of anti-corrosive finishes are briefly referred to.

Galvanic Corrosion. I. Current Flow and Polarization Characteristics of the Aluminium–Steel and Zinc–Steel Couples in Sodium Chloride Solution. M. J. Pryor and D. S. Keir. (*J. Electrochem. Soc.*, 1957, **104**, May, 269–275). Current flow, weight loss, and polarization measurements were made in N NaCl at 25° C. Effects of stirring are noted, the rates being controlled by O_2 depolarization.

The Corrosion Resistance of Wrought Iron. J. P. Chilton (*University of Cambridge Abstracts of Dissertations*, 1954–1955, 182–183). Three zones are defined one corroding quickly, one resistant, and one very resistant to attack, called Q, R, and V zones. The last-named are formed by " piling " and are high in Cu, Ni, and P. Piling of steel is suggested and recommendations for improving wrought iron are made.

Corrosion with some Reference to Railway Materials. A. M. Edwards. (*Rail. Steel Topics*, 1957, **4**, Spring, 25–33). A discussion including boiler corrosion and water treatment.

Corrosion Problems in Nuclear Power Production. A. B. McIntosh. (*Chem. Indust.*, 1957, June 1, 687–692). Some observations on steels are included.

Studies on Corrosion at Power Generation Stations using Acid River Water. VII; VIII. On the Relationships between the Natural Electrode Potential and the Corrosion Rate. 1; 2. S. Shimodaira. (*Nippon Kinzoku Gakkai-Si*, 1954, **18**, Nov., 566–569; 570–573). [In Japanese]. 1. Equations are given for corrosion rate. In the case of cathodic (activation) control, it is a function of the rate constant of the cathodic reaction, the concentration of adsorbed molecules, and the natural electrode potential. In the case of mixed control (by activation at the cathode and diffusion at the anode), it is a function of pH and the standard electrode potential of the metal. (12 references). 2. A formula is given for natural electrode

potential. From this, predictions are made of the corrosion to be expected with Hg, Bi, Cu, Ag, Ni, Pb, Sn, Cr, Fe, Cd, and Al under various pH conditions. With iron in air-free solutions, corrosion with evolution of hydrogen should cease at pH 9. (14 references). **IX. On the Change in Natural Electrode Potential Produced by Motion.** H. Endo, S. Shimodaira, and Y. Sawada. (*Nippon Kinzoku Gakkai-Si*, 1954, **18**, Dec., 610–613). [In Japanese]. The effect of relative motion between electrode and solution was examined in dilute acid and alkaline solutions. Mild steel became more positive in behaviour; 16% Cr steel showed a similar effect of greater magnitude. With copper there was a point above which the potential became more positive and below, more negative. Aluminium always became more positive. The results are explained by the local cell theory. **XIII. On Cavitation Corrosion. I.** S. Shimodaira, Y. Sawada, and N. Ootani. (*Nippon Kinzoku Gakkai-Si*, 1955, **19**, Mar., 209–212). [In Japanese]. Damage to carbon steels in acid solutions, produced by ultrasonic means, was shown to be caused by an electrochemical reaction and the direct force of water; the former effect was more pronounced in oxidizing solutions. Resistance to cavitation increased with corrosion resistance and hardness.

Electrochemical Properties of Alloys. III. The Effects of Hydrogen and Chlorine Ions on the Anodic Behaviour of Iron–Chromium Alloys in Sulphuric Acid Solution. IV. The Effects of Chlorine Ions on the Anodic Behaviour of Iron–Chromium Alloys in Sulphuric Acid Solution. S. Morioka and K. Sakiyama. (*Nippon Kinzoku Gakkei-Si*, 1954, **18**, Dec., 643–646; 647–650). [In Japanese]. III. The magnitude of anodic polarization depends on the conductivity of the electrolyte, and the critical current density to cause passivity falls as polarization and chromium content increase. The relationship between critical current density and the potential from which passivation sets in depends on chromium content. Passivation is hindered by chlorine ions, the effect varying with acid concentration and chromium content. IV. The inhibiting effect of chlorine ions on passivation is explained in terms of the strong oxidizing action of chlorine atoms adsorbed on the anode, and of the reduction of $Cr_2O_7^{--}$ ions to form a complex salt of Cr^{+++} ions.—K. E. J.

Electrochemical Behaviour of Alloys. VIII. Effect of Molybdenum on the Anodic Behaviour of Iron–Chromium, Iron–Nickel and Iron–Chromium–Nickel Alloys. S. Morioka and K. Sakiyama. (*Nippon Kinzoku Gakkai-Si*, 1955, **19**, Oct., 598–600). [In Japanese]. The effects of additions of 1–3% Mo on the anodic behaviour in 5% H_2SO_4 solution are studied for alloys of iron with 18% Cr, 8% Ni, 12% Ni, 18–8 Cr–Ni, and 18–12 Cr–Ni.—K. E. J.

Note on the Growth of Films on Metals. T. P. Hoar. (*J. Chim. Phys.*, 1956, **53**, Oct., 826–831). A short review of theoretical approaches made to the mechanism of the growth of oxide films on metals is presented.—B. G. B.

On the Mechanism of the Oxidation of Metals. Following a Non-Parabolic Law. K. Hauffe. (*J. Chim. Phys.*, 1956, **53**, Oct., 855–870). A theoretical study is made of the mechanism for the oxidation of metals. Some results for iron are cited.—B. G. B.

Vacuum Installation for Studying the Kinetics of Reduction and Oxidation Processes. D. M. Chizhikov and G. G. Gvelesiani. (*Zavodskaya Laboratoriya*, 1956, **22**, (4), 499–501). [In Russian]. An apparatus has been developed in which high-temperature oxidation or reduction processes are followed by continuously weighing the sample. Constant temperature and pressure are maintained automatically.
S. K.

Study of Cathodic Reduction of Oxide Films on Iron. I. Reductions of Alpha- Fe_2O_3 Films. H. G. Oswin and M. Cohen. (*J. Electrochem. Soc.*, 1957, **104**, Jan., 9–16). Apparatus and technique is described and measurements are reported in buffered and unbuffered electrolytes. Effects of pH, dissolved oxygen, current density and film thickness are discussed. Methods of determining α-Fe_2O_3 in thin films are suggested.

The Structure of Superficial Oxidation Films. R. Collongues and R. Sifferlen. (*J. Chim. Phys.*, 1956, **53**, Oct., 803–809). The structure of compact films of FeO and Cu_2O has been studied.—B. G. B.

Kinetics of Formation of Porous or Partially Detached Scales. C. E. Birchenall. (*J. Electrochem. Soc.*, 1956, **103**, Nov., 619–624). In a study of the rate equations, the growth rate of oxide scales on metals is shown to be strongly affected by the development of porosity which is related to the plasticity of both metal and the scale.—A. D. H.

The Reactions of Iron–Nickel Alloys with Oxygen. M. J. Brabers, W. J. Heideger and C. E. Birchenall. (*J. Chim. Phys.* 1956, **53**, Oct., 810–816). The results are given of an investigation into the oxidation of iron–nickel alloys at 1050 and 1095° C in oxygen and air. The oxide films have been examined chemically, optically and by X-ray diffraction and their structure and composition determined. The results enable certain conclusions to be drawn concerning the kinetics of the oxidation of such alloys.—B. G. B.

Selective Oxidation of Iron–Chromium Alloys in the Region of the Dissociation of Cr_2O_3. J. Moreau and J. Bénard. (*J. Chim. Phys.*, 1956, **53**, Oct., 787–797). The results of a detailed study of the oxidation of iron–chromium alloys at temperatures between 1050 and 1300° C and pH_2O/pH_2 ratios between $1{\cdot}5 \times 10^{-4}$ and $2{\cdot}5 \times 10^{-2}$ are given. The oxide structure and appearance depends on the oxygen potential of the gas phase and electron micrographs of typical surface structures are reproduced.—B. G. B.

Corrosion in Scotch Marine Boilers. I. Model Boiler Tests on the Corrosion of Mild Steel Tubes in Highly Saline Waters. F. Wormwell, G. Butler, and J. G. Beynon. **II. Model Boiler Tests on the Influence of the Copper Content of the Steel on the Corrosion of Tubes in Artificial Sea Water.** G. Butler and H. C. K. Ison. (*Trans. Inst. Marine Eng.*, 1957, **69**, Apr., 109–120, 121–128. Discussion, 137–148).

The Action of Oxygen on Zinc and Iron. D. E. Davies. (*University of Cambridge Abstracts of Dissertations*, 1954–1955, 184–185). Iron was studied at 175–350° C.

Researches on the Mechanism of Oxidation of Single Crystals of Iron at High Temperatures and Low Oxygen Pressures. J. Bardolle. (*Pub. Sci. Techn. l'Air*, 1957, No. 327, pp. 62). A physico-chemical investigation of the formation of FeO on iron surfaces is reported. Surface preparation is described and oxidation up to 850° C at between 1·0 and 10^{-3} mm O_2 is examined by metallographic and interference methods. It is observed that nucleation begins at isolated spots depending upon conditions and crystal habit and in some cases epitaxis occurs. (35 references).

The Mechanism of Formation of Metal Particles in the Scale on Nickel Steel. K. Sachs. (*J. Iron Steel Inst.*, 1957, **187**, Oct., 93–104). [This issue.]

Studies on the Oxidation Characteristics of High Carbon Steel at Different Electrostatic Potentials. K. C. Som, R. Ganguly, and G. P. Chatterjee. (*Trans. Indian Inst. Met.*, 1955–56, **9**, 183–193). The effects of electrostatic potentials on the oxidation characteristics of a 1% carbon steel under a temperature gradient condition when exposed to dry air were studied. The specimens were charged to $\pm$ 12 volts. It was concluded that: (*a*) the rate of oxidation of a neutral specimen is greater than that of a positively or negatively charged specimen, (*b*) the negatively charged specimen is less reactive in the initial stages of oxidation than when charged positively. At later stages the converse is true, (*c*) the inverse of time t required to form a particular type of oxidized layer is related to the absolute temperature T by an expression involving an activation energy and the Boltzmann constant.—D. H.

Fretting Corrosion. J. J. Spillman. (*J. Inst. Auto. Aeronaut. Eng.*, 1957, **17**, Feb., 44–52). A review of the process, the mechanisms suggested and experimental findings is given. Failures associated with it are described and protective measures reviewed.

On the Effect of the Sulphur Content of Slag Wool on its Corrosion Properties. H. E. Schwiete, L. Žagar, P. Dickens, and P. König. (*Arch. Eisenhüttenwesen*, 1957, **28**, Apr., 187–194). Results are reported of tests to determine whether the sulphur content of various mineral wools affected the corrosion of insulated boilers and pipe lines. Sheet metal samples wrapped in mineral wool with and without sulphide content were exposed to indoor and outdoor atmospheres for nine months. The effects of moisture absorption and packing density of the wools were determined. The sulphides in the mineral wool were found not to promote corrosion.—L. J. L.

The Kesternich Corrosion Test. (*Electroplating Metal Finishing*, 1957, **10**, May, 157). A method using an artificial industrial atmosphere is briefly described. CO_2–SO_2 mixtures are used with moisture and the results and the source of the apparatus are given.

Apparatus for Investigating Corrosion in Flowing Liquids and Highly Aggressive Media. V. Seifert, J. Vorliček, K.

Smrček, and I. Sekerka. (*Chem. Listy*, 1957, **51**, (5), 986–987).

Nomograph Gives Numerical Estimate of Galvanic Corrosion. H. Blye. (*Machine Design*, 1957, **29**, Jan. 10, 139). Metals in contact are characterized by arbitrary units to show extent of corrosion and which of the pair is protected.

A Hydrogen Effusion Method for the Determination of Corrosion Rates in Aqueous Systems at Elevated Temperature and Pressure. M. C. Bloom and M. Krulfeld. (*J. Electrochem. Soc.*, 1957, **104**, May, 264–269). Measurements on low-carbon and stainless steels are reported.

Avoidance of Stress Corrosion in Austenitic Steel Equipment. C. Edeleanu. (*Chem. Process Eng.*, 1957, **38**, May, 181–184). Chlorides and caustic hydroxides produce cracking in all austenitic steels and avoidance of such conditions are more important than changes of alloy composition. Increased nickel steels show some resistance.

Cathodic Protection in the U.S. Navy. D. P. Graham, F. E. Cook, and H. S. Preiser. (*Shipbuilder and Marine Engine Builder*, 1957, **64**, Mid-Apr., 316–324).

***cyclo*Hexylamine Carbonate as a Voiatile Corrosion Inhibitor.** C. A. Rhodes. (*Corrosion Prevention and Control*, 1957, **4**, Apr., 37–39, 42). Tests are described.

The Prevention of Corrosion by Paints Containing Metallic Pigments or Buffer Substances. C. E. Bird. (*University of Cambridge Abstracts of Dissertations*, 1954–1955, 180–182). Sprayed Al and Zn coatings are studied, also iron pigments.

ANALYSIS

ASTM Methods of Chemical Analysis of Metals 1956. (*Amer. Soc. Test. Mat.*, Nov., 1956, pp. 627). **Apparatus and Reagents for Chemical Analysis of Metals.** (1–40). **Photometric Methods for Chemical Analysis of Metals.** (41–51). **Designating Significant Places in Specified Limiting Values.** (52–56). **Standard Method of Sampling Steel, Cast Iron, Open-Hearth Iron and Wrought Iron.** (57–61). Unchanged from 1945. **Standard Methods of Sampling of Ferro-Alloys.** (62–68). Unchanged from 1942. **Chemical Analysis of Steel, Cast Iron, Open Hearth Iron, and Wrought Iron.** (75–160). Revised 1952, 1956. New tentative method 1956 including Mn by periodate method, Ni by dimethylglyoxime method, Mg by oxyquinolate (Hg cathode) method, Nb and Ta by hydrolysis (photometric) method and S by direct combustion–iodate titration method. **Chemical Analysis of Ferro-alloys.** (161–196). Unchanged since 1947. **Tentative Methods for Chemical Analysis of Ferro-alloys.** (197–203). Issued 1954. Fe–W and W metal, Fe–Ti. **Chemical Analysis of Nickel–Chromium and Nickel–Chromium–Iron Alloys.** (204–219). Revised 1956. Methods for Ni, Cr, Fe, C, Mn, S, Si, Al, Ti, Zr, Ca, Mg, and Co. **Tentative Methods for Chemical Analysis of Nickel–Chromium and Nickel–Chromium–Iron Alloys.** (220–224). Issued 1956. Mn by periodate (photometric) method and Cu by Neo-Cuproine (photometric) method. **Weighing and Drying Apparatus for Microchemical Analysis.** (594–604). Issued 1956.

A Complete Chemical Analysis in 45 Minutes. W. T. Unfried. (*Mod. Castings*, 1956, **29**, Apr., 86–91). Si, P, Mn, Cr, V, Ni, Mo and Cu can be determined.

Studies on Chemical Analysis of Ferro-alloys by J.I.S. Methods. I. T. Imai and S. Togashi. (*Nippon Kinzoku Gakkai-Si*, 1954, **18**, Nov., 603–606). [In Japanese]. Analytical methods for iron and steel are not always appropriate for ferro-alloys. An assessment is made of errors in analyses of ferro-alloys arising from analytical methods or segregations.

The Use of Elution Chromatography from Cellulose Columns for the Systematic Analysis of Special Steels. G. Venturello and A. M. Ghe. (*Analyst*, 1957, **82**, May, 343–352). 0·25 g samples were used and Mo, Co, Mn, V, Ni, and Cr were determined with accuracy equal to that of conventional methods.

The Heterogeneous Distribution of Oxygen in Cast Iron. G. Blanc and A. Blondel. (*Brit. Found.*, 1957, **50**, May, 245–257). A vacuum fusion process is described for determination of oxygen and oxygen content is related to location of samples, casting method, storage conditions, and mould material. Contents were highest near feeders and other areas liable to inclusions and within 1 mm of surfaces, especially after storage in air. Conclusions are drawn. (30 references).

Polarographic Determination of Iron using Saccharose as a Complex-forming Reagent. O. Manoušek. (*Chem. Listy*, 1957, **51**, (5), 854–860).

Polarographic Reduction of Iron (III) Ions in Presence of Ethylenediaminetetra-acetic Acid and Hydrogen Peroxide. I. The Pseudomonomolecular Reaction in Aqueous Solution. B. Matyska and D. Duškova. **II. Bimolecular Reaction in Aqueous Solution.** B. Matyska. (*Chem. Listy*, 1957, **51**, (5), 839–847; 848–853).

Polarographic Behaviour of Cd, Cu, Pb, Ni, Co, Zn and Fe in Ethanolamines and K_2SO_4 or KNO_3. R. S. Subrahmanya. (*J. Indian Inst. Sci.*, 1956, **38**, Oct., 245–248). The complexes formed are suggested.

Determination of Aluminium in Aluminium–Iron Alloys. J. V. Gilfrich. (*Anal. Chem.*, 1957, **29**, June, 978–980). Interfering elements are removed by adsorption on a column and Al determined gravimetrically as hydroxide.

The Effect of Chromium in the Bismuthate Method for the Determination of Manganese. W. E. Clarke and W. B. Shaw. (*Brit. C.I. Res. Assoc. J. Res. Dev.*, 1957, **6**, Feb., 512–518). It was found that Cr in amounts up to 5% does not interfere in the analytical method provided a sufficient excess of H_2SO_3 is added after the first (hot) bismuthate oxidation to ensure reduction of all CrO_4 formed.—B. G. B.

Electrolytic Determination of Lead in Iron and Steel. H. Goto and Y. Kakita. (*Sci. Rep. Res. Inst. Tôkoku Univ.*, 1957, **9**, Apr., 131–137).

Rapid Determination of Magnesium in Iron. R. Reichert. (*Giesserei*, 1957, **44**, Jan. 17, 51–52). Various methods for the determination of Mg are first reviewed. The titration method of Schwarzenbach and Biedermann is then described. Finally the working method proposed is given, numerically, in detail.

On the Accuracy of the Volhard Method for the Determination of Manganese. Y. Oka and T. Kanno. (*Nippon Kinzoku Gakkai-Si*, 1954, **18**, Oct., 552–556). [In Japanese]. Causes of error in the method are shown to be adsorption of Mn ions on solid ZnO and adsorption of manganous ions on MnO_2; the latter effect is reduced in presence of excess zinc salts.

Polarographic Determination of Tin and Antimony in Iron and Steel. H. Goto, S. Ikeda, and S. Watanabe. (*Sci. Rep. Res. Inst. Tôhoku Univ.*, 1957, **9**, Apr., 97–106).

Photometric Determination of Titanium in Steel using Chromotropic, Gallic or Pyrogallolcarboxylic Acids. L. Sommer. (*Chem. Listy*, 1957, **51**, (5), 875–879).

Determination of Zirconium in Steel. Direct Spectrophotometric Method. R. B. Hahn and J. L. Johnson. (*Anal. Chem.*, 1957, **29**, June, 902–903).

A New Method for the Determination of Sulphate in Chromium Plating Solutions. C. J. Keattch. (*Electroplating*, 1957, **10**, Jan., 2–6). A detailed account is given of the development of the determination of sulphate by reduction to sulphide which is then estimated volumetrically. The method is accurate for unworked and worked solutions.—A. D. H.

Rapid Determination of Calcium and Magnesium in Limestone and Dolomite Using Complexone III. J. Deren, J. Haber, and J. Nedoma. (*Chemia Anal.*, 1957, **2**, (1), 3–10). [In Polish].

Study of Rapid Determination of Slag Basicity Using Aqueous Slag Suspensions. L. Pöcze and I. Farkas. (*Kohászati Lapok*, 1956, **11**, (6), 254–257). In connection with a conductometric method for slag basicity determination a pure chemical method was elaborated based on the rapid analysis of dissolved calcium ions by complexometric titration. The calcium ion concentration of aqueous slag suspensions being proportional to their basicity.—P. K.

A Complete Slag Analysis in 45 Minutes. W. T. Unfried. (*Mod. Castings*, 1956, **30**, Dec., 32–34). Determinations of Ca, SiO_2, Mn, Fe oxides, P and Cr are given.

Polarographic Determination of Lead, Copper and Zinc in Pyrites, Marcasites, and in Spent Oxides. K. Lasiewicz and H. Zawadzka. (*Chemia Anal.*, 1957, **2**, (1), 22–28). [In Polish].

Spectrographic Determination of the Basicity of Slag. S. Bergenfelt. (*Jernkontorets Ann.*, 1957, **141**, (4), 231–232).

Spectrographic Analysis of Open Hearth Slags by the Copper Cup–Electrode Solution Method. Ho I-Djen and Li Shih-Cho. (*Acta Chimica Sinica*, 1956, **22**, (1), 55–65). A HNO_3 solution with $SnCl_2$ (as internal standard) and KBr (for stabilization of the arc) is used. The Ca : Si ratio in 20 samples agreed with the chemical value within 5%. Complete analyses have also been carried out. Turbulence during arcing is advantageous.

Spectrographic Determination of Small Amounts of Silicon and Tin in Iron and Steel by the Intermittent Arc Method. T. Takai. (*Nippon Kinzoku Gakkai-Si*, 1954, **18**, Nov., 582–583). [In Japanese]. A unit in which the frequency of interruption and also the ratio of arc duration to interruption time could be varied continuously, in combination with a Littrow

type or medium quartz spectrometer, gave satisfactory results for 0·008–0·163% Si and 0·010–0·145% Sn.—K. E. J.

Studies on Spectrophotometry. IX. Simultaneous Determination of Manganese and Chromium in Iron and Steel. T. Kanno. (*Nippon Kinzoku Gakkai-Si*, 1954, **18**, Dec., 625–629). [In Japanese]. The best conditions for the simultaneous determination include oxidation of Mn by KIO_4 and careful control of the concentration of H_3PO_4. Mn is determined at 565 mμ. with negligible interference from Cr. (11 references).

Applications of X-Ray Emission Spectrometry to Rock and Ore Analysis. G. R. Webber. (*Canad. Min. Met. Bull.*, 1957, **50**, Apr., 222–227). Determinations of Nb, Fe, Ti, CaO, and K_2O are described and compared with chemical analyses.

The Use of Atomic Energy in the Testing of Materials. W. M. Keller. (*Mech. Eng.*, 1957, **79**, Mar., 258–260). Railway applications of isotopes are described.

The Use of Radioactive Tracers. R. F. Littlejohn and D. H. T. Spencer. (*Brit. Coal Utilisation Res. Assoc. Monthly Bull.*, 1957, **21**, Feb., 53–64). A brief general account of isotope techniques, particularly in studies of fuel. (106 references).

How can Radioactive Isotopes Help the Metallurgist? R. Forbath and E. Kalmar. (*Kohászati Lapok*, 1956, **11**, (7) 305–309). After referring to the principles of radioactivity and reviewing its application in other countries the author comments on the projects of future Hungarian experiments such as the control of the blast furnace lining thickness observation of the change of sulphur content in the bath of an oil-fired O.H. furnace, measurement of the solution velocity of ferromanganese in steel heats and tests on some radiometric analysis methods.—P. K.

Conference on the Use of Radioactive Isotopes in Ferrous Metallurgy. A. I. Stroganov. (*Stal'*, 1956, (6), 568). [In Russian]. Recent research work on iron and steel in the Soviet Union involving radioactive isotopes is described in this account of a conference held in Magnitogorsk in January, 1956. Representatives from the main works and research and educational institutes attended.—S. K.

Use of Radioisotopes for Measurements in Czechoslovak Metallurgy. J. Kuba. (*Problems and Perspectives in Czechoslovak* Metallurgy and Foundry, 1956, 292–297). Thickness measurements of hot-rolled sheets and thin foils and of cold-rolled strip are described using the radiations from ^{90}Sr, ^{204}Tl and ^{60}Co.

Analytical Methods Using Manganese (III) Phosphate, II, Preparation of the Reagent. K. Tanino. **III. A Rapid Method of Determining Ferrous Oxide in Acidic Slags.** S. Kitahara and K. Tanino. (*Res. Sci. Res. Inst.*, 1956, **32**, Abstracts **26**, 2). **IV. A New Rapid Method of Analysing Manganese Dioxide in Manganese Ore.** K. Tanino. (10–11).

A Rapid Method of Determining Calcium and Magnesium in the Slag of Blast and Steel Making Furnaces by EDTA. S. Kitahara, S. Hara and K. Watanabe. (*Rep. Sci. Res. Inst.*, 1956, **32**, Abstracts, **26**, 10).

On a New Method of Attack on Refractories for Analytical Purposes. (*Compt. Rend.*, 1957, **244**, Jan. 14, 354–356). A method using chalk and without a crucible in which the mixture is heated on a surface of water-cooled metal (Al) in the solar furnace is described.

Applications of [Autoradiography] to Metallurgy. I. Study on the Behaviour of Iron in Aluminium of High Purity by the Use of Fe–59. M. Kato and M. Kobayashi. (*Nippon Kinzoku Gakkai-Si*, 1955, **19**, Oct., 616–619). [In Japanese]. Aluminium of 99·99% purity was alloyed to contain 0·064% of iron "tagged" with ^{59}Fe and ^{55}Fe. In the cast form, rapidly cooled, most of the iron was segregated in dendrites not easily diffused by solution heat-treatment. On cold-reduction by about 20%, a V-shaped slip pattern was given. In the rolled structure, iron was partially dissolved in the matrix by solution heat-treatment. (17 references).—K. E. J.

The Colorimetric Determination of Cadmium, Chromium, Copper, Iron, Lead, Manganese, Nickel and Zinc in Sewage and Industrial Wastes. A. A. Christie, J. R. W. Kerr, G. Knowles, and G. F. Lowden. (*Analyst*, 1957, **82**, May, 336–342).

Scale Pit Effluents. R. D. Hoak. (*Mellon Institute of Industrial Research Progress Report of Amer. Iron Steel Inst. Fellowship No.* 278–19, 1957, Jan., 471–474; Feb., 496–509; *Special Report No.* 8, Apr., 3–4). Scale pit effluents were sampled and examined by turbidimetry which appeared to be capable of affording an analytical method for total solids. Statistical analyses of sampling frequency is then reported and length and quantity of sampling is determined sufficient when correlated with mill operation.

Toxicity of Effluents. R. D. Hoak. (*Mellon Institute of Industrial Research. Special Report No.* 8 *of Amer. Iron Steel Inst. Fellowship No.* 278–19 *for the Water Quality Sub-Committee of the Steel Industry Committee of the Ohio River Valley Water Sanitation Commission*, 1957, April, 6–18 + xxxii). Tabulated data on the biological effects of ammonium compounds, cresols, iron cpds., Mn salts, naphthalene, phenol, pyridine and homologues, sulphur compounds and tin salts are reported. Effects on numerous organisms, animals and man included, are given.

INDUSTRIAL USES AND APPLICATIONS

Pearlitic Malleable Iron Crankshafts. (*Automobile Eng.*, 1957, **47**, May, 179–181). Developments for the Pontiac V–8 engine are described. Physical properties and wear characteristics of the iron are given and a study of the effect of cold work on fatigue properties is briefly reported.

Materials for Nuclear Power Reactors. (*Mat. Methods*, 1956, **44**, Aug., 121–144). (Manual No. 129). Shielding, coolants, fuels, structural materials, control and moderator–reflector substances are briefly reviewed. Steels are considered for shielding and structural purposes and boron steel for controls.

Corrosion Resistant Steel Tubes. T. Gibbs. (*Corrosion Prevention and Control*, 1957, **4**, Apr., 41–42). A brief review of uses.

Ductile Iron. Eliminates Breakage Problem in Reel Spiders on New Grain Grader. (*INCO*, 1957, **26**, Feb., 23). Ductile iron is substituted for grey cast iron.

Metallurgical Considerations of Main Steam Piping for High-Temperature, High-Pressure Service. H. S. Blumberg. (*Blast Furn. Steel Plant*, 1957, **45**, Feb., 220–224, 250–251). A review of the developments made in steel for steam piping is presented. Particular reference is made to the metallurgical aspects which determine the suitability of a steel for use under these conditions. An increased use of austenitic steels must be made if operating temperatures and pressures continue to rise. Then austenitic steel tubes could replace the heavier ferritic tubes now in service.—B. G. B.

The Design of Pressure Vessels and Pipes for High Temperatures. W. P. Kerkhof. (*Lastechn.*, **23**, 1957, May, 76–82). [In Dutch]. The author summarizes present knowledge concerning creep in steel. Critical mention is made of the usual creep tests and theoretical explanations are offered with regard to influences exerted by increased stresses and the differences in the rate of creep of component parts. A safety factor of 1·5 to the stress at rupture value over 100,000 hours is suggested ignoring the total creep or creep rate as such. It is proposed to collect together sketches of adequate welding details, some examples of which appear in the text. Further work is to be done, notably on the standardization of creep tests, durability of materials, recommendations for high temperature controls and the tendency to brittle fracture.

HISTORICAL

Etruscan Mines and Metallurgical Installations. G. Caneva. (*Fonderia Ital.*, 1957, **6**, April, 162–165, 175). [In Italian]. The author describes the iron ore mines dating back to Etruscan times and a number of iron smelting furnaces found in the neighbourhood of Campiglia Marittima.—M. D. J. B.

The First 25 Years of Pre-historical Research in the Siegerland by Digging at Ancient Iron Works. J. W. Gilles. (*Arch. Eisenhüttenwesen*, 1957, **28**, Apr., 179–185). Construction and method of operation of ancient charcoal hearths have been investigated.—L. J. L.

A Double Centenary. (*Rail. Steel Topics*, 1956, **3**, Autumn, 15–24). An account of the Workington Haematite Iron Co. founded in 1856 and of the Bessemer process. Present practice is described.

A Forgery in Iron. H. R. Schubert. (*J. Iron Steel Inst.*, 1957, **187**, Oct., 125). [This issue].

The Centenary of the Steel Rail. J. Dearden. (*Rail. Steel Topics*, 1957, **4**, Spring, 11–24).

ECONOMICS AND STATISTICS

The Functioning of the Common Market for Steel Within the European Coal and Steel Community. T. Rollman. (*Jernkontorets Ann.*, 1957, **141**, (4), 181–188). [In English].

Raw Materials in the Automotive Industry. J. S. Anderson. (*Trans. Australian Inst. Met.*, 1954–55, **7**, **8**, 211–222). Statistical, and including non-metals.

The Cyclic Flow of Metals. C. Blazey. (*Trans. Australian Inst. Met.*, 1954–1955, **7**, **8**, 205–210). An address. Statistics are presented of the use and reuse of metals.

MISCELLANEOUS

Computers and Steel. D. G. Owen. (*BISRA publication*, 1957, pp. 24). The automatic electronic digital computer is described and a discussion of its uses in the industry, mainly, as yet, in accountancy.

Demonstration of BISRA Performance Recorder. (*Instrument Practice*, 1957, **11**, May, 492–494).

Desulphurisation of Alloys in Hydrogen. B. Chatterjee and K. R. Sangameswaran. (*Trans. Indian Inst. Met.*, 1955–56, **9**, 161–165). Studies have been made of the removal of sulphur from powdered samples of cast iron containing 0·36% and 0·47% S and from drillings of steel containing 0·35 and 0·22% S on heating at 1000° C in a current of dry H_2 or H_2 containing 1·2% by volume of water vapour. Both atmospheres produced desulphurization, moist hydrogen being more effective than dry. The mechanism of sulphur removal is discussed.—D. H.

Maintenance Viewpoints. J. Serenka. (*Yearly Proc. Assoc. Iron Steel Eng.*, 1956, 744–747). General discussions from management and maintenance department viewpoints are given.

The Extraction of Tungsten from High Speed Steel Grinding Swarf and Scale. F. H. Scott. (*Metallurgia*, 1957, **55**, 140–142). The process described is claimed to be an economic proposition on a pilot plant scale for finely divided material. A modification of the Oxland process used in the extraction of tungsten from its ores is employed.—B. G. B.

Nuclear Technology and the Steel Industry. R. P. Petersen. (*Iron Steel Eng.*, 1957, **34**, April, 124–127). This paper explores some of the possibilities which nuclear technology may have for the steel industry.—M. D. J. B.

BOOK NOTICE

Roos, A. "*Précis de Metallographie Appliquée (Aciers et Fontes).*" La. 8vo, pp. xvi + 381. Illustrated. Paris, 1957: Dunod.

This book deals with a variety of subjects mainly in the field of iron and steel metallurgy. There are chapters on micrography and macrography, crystal structure, electronic theory of metals, X- and gamma-radiography, microradiography. Much space (possibly too much) is given to a description of tensile, impact hardness, creep and fatigue testing and to ultrasonic examination. The book ends with a homily on methods and organisation of research.

Parts of the book are well-written and the matter is presented in a novel but very useful manner, but unfortunately there are many sections of which considerable criticism can be made. Most of the references are French, during the period 1890 to 1920, and work done since 1945 receives scant attention.

There are some glaring omissions. Thus, no reference is made to the classical work of Cohen in America on the martensite transformation, to Holt's excellent book on twinning, to the work of Ko and Cottrell on bainite formation and to many other researches in this field. The section on pearlite formation and growth is full of errors.

Only the briefest reference is made to 13% chromium steels and none to the austenitic stainless steels. The lower limit for sigma phase is stated to be 30% chromium, and not 13%, as it has now been shown to be. There is no mention of 475° C embrittlement.

In the chapter on fatigue there is no mention of the effects of notches or of corrosion.

Space available for this review does not permit of a more detailed criticism of the book, but there are many printing errors which detract from its value.—J. Woolman.

NEW PUBLICATIONS

"*Atlas Metallographique de Microstructures Types.*" Sommaire: Fontes et Aciers; Alliages d'Aluminium; Alliages Cuivreux. La. 8vo; three sections of 12 pp. each, two of 20 pp. each, unbound. Illustrated. Paris [1957]: Editions Techniques des Industries de la Fonderie.

Bourdon, H. "*Aciéristes et Fondeurs. Le Four Électrique Basique.*" 8vo, pp. 132. Illustrated. Paris, 1957: Dunod. (Price 880 fr.).

Bowman, Edward H., and Robert B. Fetter. "*Analysis for Production Management.*" 8vo, pp. xiii + 503. Illustrated. Homewood, Illinois, 1957: Richard D. Irwin, Inc. (Price $6.50).

Burgess, C. O. "*Heat Treatment of Gray Iron.*" 8vo, pp. 117 + vi. Illustrated. Cleveland, Ohio, 1954 : Gray Iron Founders' Society, Inc. (Price 40*s*. 6*d*.).

Carter, C. F., and B. R. Williams. "*Industry and Technical Progress.*" Factors Governing the Speed of Application of Science. [Prepared] on behalf of the Science and Industry Committee. 8vo, pp. viii + 244. London, New York, Toronto, 1957 : Oxford University Press. (Price (in U.K. only) 25*s*.).

de Smet, G. "*La Pratique des Traitements Thermiques des Métaux Industriels.*" 5e Édition. La. 8vo, pp. xxiv + 466. Illustrated. Paris, 1957 : Dunod. (Price 3300 fr.).

Green, H. L., and W. R. Lane. "*Particulate Clouds: Dusts, Smokes and Mists.*" Their physics and physical chemistry, and industrial and environmental aspects. La. 8vo, pp. xix + 425 + 7 plates. London, 1957: E. & F. N. Spon, Ltd. (Price 70*s*.).

Hilly, G. et C. Chaussin. "*Cours de Métallurgie. Élaboration des Métaux.*" La. 8vo, pp. xvi + 187. Illustrated. Paris, 1957: Dunod. (Price 680 fr.).

Holland, L. "*Vacuum Deposition of Thin Films.*" With a Foreword by Professor S. Tolansky. 8vo, pp. xix + 541 + 25 plates. Illustrated. London, 1956: Chapman and Hall, Ltd. (Price 70*s*.).

Huber, M. T. "*Works.*" Vol. III. "*Problems: General Mechanics, Engineering Construction, Reinforced Concrete Construction, Soil Mechanics, Construction of Machines, Construction of Aircraft, Contributions to a Technical Dictionary.*" [In Polish]. La. 8vo, pp. xi + 504. Illustrated. Warsaw, 1957: State Science Publishers.

"*Laboratory and Workshop Notes* 1953–1955." A fourth selection reprinted from the *Journal of Scientific Instruments*, compiled and edited by Ruth Lang for the Institute of Physics. 8vo, pp. xii + 248. Illustrated. London, 1957: Edward Arnold (Publishers), Ltd. (Price 30*s*.).

Lister, Raymond. "*Decorative Wrought Ironwork in Great Britain.*" 8vo, pp. xii + 265. Illustrated. London, 1957 : G. Bell and Sons, Ltd. (Price 35*s*.).

Loskiewicz, Wladyslaw and Marian Orman. "*Uklady Rownowagi Podwojnych Stopow Metali.*" (Constitutional Diagrams of Binary Metal Alloys). With English Contents and Summary. 4to, pp. 362. Illustrated. Warsaw, 1956: State Science Publishers. (Price, Zloty 53.50).

Niezoldi, Otto. "*Ausgewählte chemische Untersuchungsmethoden für die Stahl- und Eisenindustrie.*" 5te Auflage. 8vo, pp. viii + 189. Berlin/Göttingen/Heidelberg: 1957. Springer-Verlag. (Price, DM 15.60).

Sporck, J. A. "*L'Activité Industrielle dans la Region Liegeoise.*" Étude de Géographie Économique. Ouvrage publié avec le concours de la Fondation Universitaire, du Ministere des Affaires Économiques, de l'A.S.B.L. le Grand Liège. La. folio, pp. 152. Illustrated. Liège, 1957: Georges Thone. (Price 47*s*. 6*d*.).

Trinks, W. "*Les Fours Industriels.*" In 2 volumes, translated into French by J. Bernot. Vol. I. 8vo, pp. xii + 548. Vol. II. 8vo, pp. xii + 356. Illustrated. Paris, 1957: Dunod. (Price, Vol. I, fr. 5900; Vol. II, fr. 4200).

United States Bureau of Mines. "*Minerals Yearbook* 1953. *Volume* 1. La. 8vo, pp. viii + 1373. Washington, 1956: U.S. Govt. Printing Office. (Price $4.50).

Wiltshire, W. J. (Editor). "*A Further Handbook of Industrial Radiography.*" By Members of the Non-Destructive Testing Group of the Institute of Physics. 8vo, pp. viii + 334. Illustrated. London, 1957: Edward Arnold (Publishers), Ltd. (Price 50*s*.).

C. T. THOMAS

CEDRIC TREHERNE THOMAS, who was born at Swansea in 1901, is the grandson of Richard Thomas, founder of Richard Thomas and Company. His father, Frank Treherne Thomas, owned the Cwmfelin Steel and Tinplate Works, and his mother was the daughter of one of the founders of the Warrington Rolling Mills and Works of Monks, Hall and Company.

Mr. Thomas was educated at Harrow, and joined his father's Cwmfelin Works as a labourer at the age of 16½. During his early years he worked in every department of the iron and steel and tinplate industry. He first joined the Redbourn Works of Richard Thomas and Co. shortly after the First World War, when he was assistant to his uncle, Capt. Wyndham Thomas, who was superintending the building of the rolling mills. He returned later as General Manager, a position which he held until the works closed down during the industrial slump of the early 1920's.

After a spell with the Export Division of the South Wales Tinplate Corporation, the sales organization of Richard Thomas and Co., during which he visited trading branches in all parts of the world, Mr. Thomas became General Manager of the Warrington Works of Monks, Hall and Co. until he was appointed Personal Assistant to Sir William Firth, who was in charge of the development of the Ebbw Vale Works, the first wide hot strip mill, complete with cold reduction sheet and tinplate mills, to be erected outside the U.S.A.

At the outbreak of the Second World War, Mr. Thomas joined the Welsh Guards, but was recalled to industry. He later rejoined the Army, and was commissioned in the Royal Army Service Corps. During the War he was responsible for the formation of the first Air Despatch Unit and organized the dropping of supplies during the Normandy landing, the Arnhem operation, and the crossing of the Rhine.

In 1945, Mr. Thomas left the Army with the rank of Colonel and rejoined the Company, which had by then become Richard Thomas and Baldwins Ltd., as Personal Assistant to the Joint Managing Director. Later he was appointed General Manager of the Company's West Wales Section, and in 1953 he returned to Redbourn as General Manager. In 1957 he transferred to the Ebbw Vale Section as General Manager.

Mr. Thomas has been a Member of The Iron and Steel Institute since 1918. He has also been a member of the Swansea Metallurgical Society for many years, and was elected President of the Lincolnshire Iron and Steel Institute in 1956; he resigned from this position when he moved to South Wales. During his tenure of office, Mr. Thomas served as an Honorary Member of Council of The Iron and Steel Institute.

C. T. Thomas

Honorary Member of Council, 1956-1957